Contents

1 Introduction

On a basic web page, we can construct and page element called a "canvas".
It needs a bit of CSS to see what we have done as it begins as an empty transparent rectangle on the page

```
<!DOCTYPE html>
<html lang="en">
<head> <meta charset="UTF-8"> <title>JavaScript</title>
    <style>
        body{ background-color: #aaaaaa; }
        canvas{
            background-color: #ffffff;
            width:800px;
            height:600px;}
    </style></head>
<body>
<canvas id='myCanvas'></canvas>
</body>
</html>
```

Listing 1: Basic Canvas

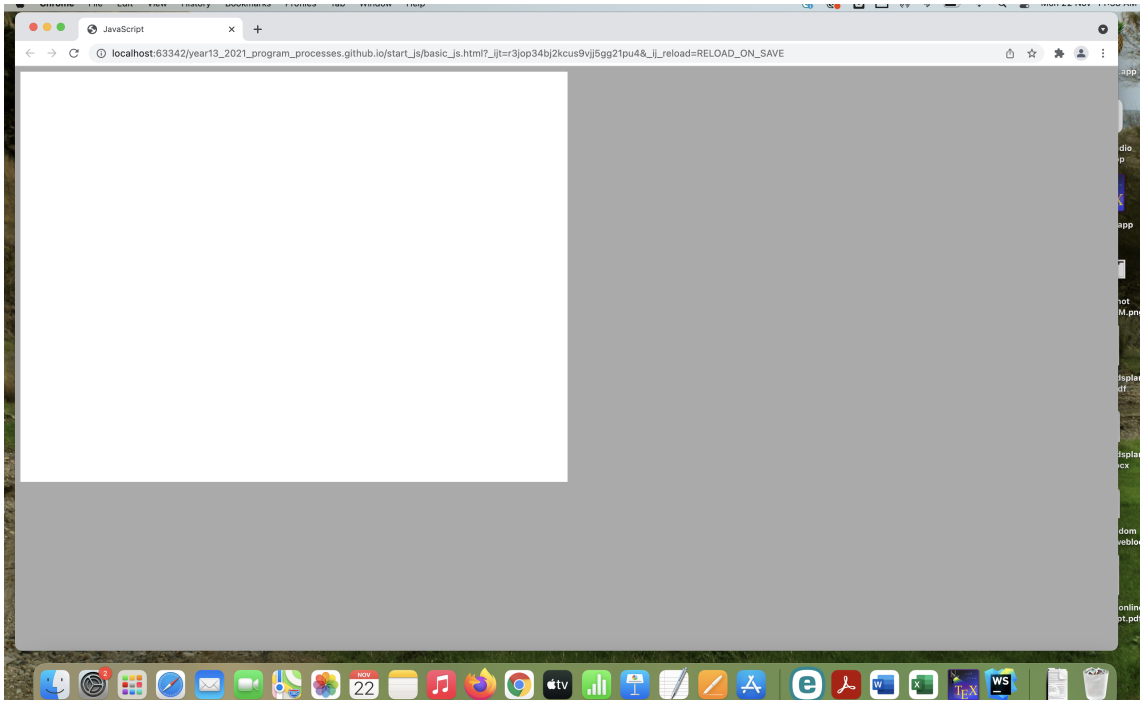


Figure 1: Canvas in browser

The canvas environment allows us to draw shapes and also run animations, so with a bit of work, we are able to create a small web applications such as games or other more interactively rich experiences. Our aim is to learn about this environment and to create a small drawing/painting program.

2 Getting started

To be able to do thing to the canvas we use JavaScript. This is a programming language and in general has many similarities to Python but has some differences in syntax.
JavaScript can be written in a web page within the < script > tag.
It can also be loaded from an external file (which we will do for most of the unit). We will have to learn quite a few things about JavaScript as we go through this unit, but regarding drawing shapes, it will always follow the same basic set of steps.

- begin a path (i.e the shape)
- define the path with its associated parameters (x,y , width, height, ..)
- define the fill, stroke and line width (do not need all)
- tell the canvas to fill and/or stroke the path

```
<!DOCTYPE html>
<html lang="en">
<head> <meta charset="UTF-8"> <title>JavaScript</title>
    <style>
        body{ background-color: #aaaaaa; }
        canvas{
            background-color: #ffffff;
            width:800px;
            height:600px;}
    </style></head>
<body>
<canvas id='myCanvas'></canvas>
<script>
    // get the canvas element using the id name
    canvas = document.querySelector('#myCanvas');
    // define a 2d context and associate it with the variable ctx
    // all canvas commands will require the ctx.
    let ctx = canvas.getContext('2d');
    // specify height and width of canvas (which should be identical to the CSS
    let width = 800;
    let height = 600;
    canvas.width = width;
    canvas.height = height;
```

```
24
25      // draw some things
26      // rectangle
27      // start the path then define as a rectangle with parameters
28      ctx.beginPath();
29      ctx.rect(10,10,100,100);
30      // set the context
31      ctx.fillStyle='rgb(0,153,204)';
32      ctx.strokeStyle='rgb(0,0,0)';
33      ctx.lineWidth=10;
34      // actually fill and stroke
35      ctx.stroke();
36      ctx.fill();
37      // the following follow exactly the same pattern
38      // circle
39      ctx.beginPath();
40      ctx.arc(200,60, 50, 0, 2*Math.PI);
41      ctx.fillStyle='rgb(255,204,51)';
42      ctx.strokeStyle='rgb(51,51,255)';
43      ctx.lineWidth=10;
44      ctx.stroke();
45      ctx.fill();
46      // line
47      ctx.beginPath();
48      // set start point of the line
49      ctx.moveTo(0, 200);
50      // set next point of the line
51      ctx.lineTo(750,200);
52      ctx.strokeStyle="rgb(255,0,0)";
53      ctx.lineWidth=1;
54      ctx.stroke();
55
56      // rectangle with a gradient fill
57
58      ctx.beginPath()
59      ctx.rect(10,350, 200,200);
60      let my_gradient=ctx.createLinearGradient(10,350,10,550);
61      my_gradient.addColorStop(0,"rgb(255,102,102)");
62      my_gradient.addColorStop(0.5,"rgb(255,255,153)");
63      my_gradient.addColorStop(1,"rgb(0,153,204)");
64      ctx.fillStyle=my_gradient;
65      ctx.fill();
66      // note that the stroke picks up the previous context
67      ctx.stroke();
68
69      // quadratic curves (bezier)
70      ctx.strokeStyle="rgb(255,0,0)";
```

```
    ctx.beginPath();
    ctx.moveTo(300,400);
    ctx.lineWidth=10;
    ctx.quadraticCurveTo(500, 550, 700, 400);
    ctx.lineCap = "round";
    ctx.stroke();


    // add text, set the context then fill the text
    ctx.fillStyle="rgb(0,0,255)";
    // shorthand css to set basic options
    let myFont= "bold 30px monospace";
    ctx.font=myFont;
    ctx.fillText("Hello World", 300,50);

    // images can be placed on the canvas but we need to know if they have loaded
    // there other ways of dealing with this
    let img = new Image();
    img.onload = function(e){
        let img_h = img.height;
        let img_w= img.width
        console.log(e);
        ctx.drawImage(img, 500,220, img_w/4, img_h/4);
    }
    img.src= "red_kangaroo.jpeg"
</script>
</body>
</html>
```

Listing 2: Basic Shapes

This just gives a "general idea" and more complete references:
https://www.w3schools.com/html/html5_canvas.asp
https://developer.mozilla.org/en-US/docs/Web/API/Canvas_API

3 JavaScript in an external file

It will become quite cumbersome having the JavaScript in the same file as the HTML page.
So it is better to have it as a separate file that is linked in.
This may make some of the code easier to re-use, as well.

```
<canvas id='myCanvas'></canvas>
<script type="text/javascript" src="basic.js"></script>
```

Listing 3: Loading javascript

4 Improving the set up

It is also helpful to add to the code that connects to that initialises the canvas.
The code below can be discussed further, but it allows us the manage the size and basic styling of the canvas from within the JavaScript.

```
canvas = document.querySelector('#myCanvas');
let ctx = canvas.getContext('2d');
// define width and height
let width = 1000;
let height = 500;
// define scale of 1. This may be changed later to improve resolution
let scale = 2;
// set the canvas width and height
canvas.width = width*scale;
canvas.height = height*scale;
// scale the canvas
ctx.scale(scale,scale);
// get the canvas element
// style it here so it will be consistent
let my_c = document.getElementById('myCanvas');
my_c.style.backgroundColor = "rgb(100,100,100)"
my_c.style.width = width+"px";
my_c.style.height = height+"px";
my_c.style.border = "6px solid rgba(200,200,200,0.5)";
my_c.style.display = "block";
my_c.style.margin = "auto";
document.body.style.backgroundColor = "rgb(190,190,190)";
```

Listing 4: Initial JS

5 Functions

We can immediately see that even drawing a small number of shapes starts tp build up code, so we want to look at ways of reducing this and having as much as possible available for "re-use". Let's look at designing a rectangle function and see what we can do with it.

Picture of design

```
/**
 * Draw a rectangle
 *
 * @param {number} x corner x
 * @param {number} y corner y
 * @param {number} w width
 * @param {number} h height
 * @param {string} fillColour rgb string
 * @param {string} strokeColour rgb string.
 * @param {number} strokeWidth x coordinate of second point.
 * @return {null}
 */
function drawRect(x,y,w,h, fillColour, strokeColour, strokeWidth){
    ctx.fillStyle = fillColour;
    ctx.strokeStyle = strokeColour;
    ctx.lineWidth = strokeWidth;
    ctx.beginPath()
    ctx.rect(x,y,w,h)
    ctx.fill();
    ctx.stroke();
```

```
}

drawRect(20,20,200,130, "rgb(232,109,135)", "rgb(236,198,76)", 2);
drawRect(20,170,200,130, "rgba(234,225,144,0.83)", "rgb(80,0,80)", 4);
drawRect(20,320,200,130, "rgba(239,89,217,0.83)", "rgb(46,169,239)", 4);
drawRect(240,20,700,430, "rgba(17,96,239,0.83)", "rgb(46,169,239)", 4);

//loop
for(let i = 0; i<26; i++){
    drawRect(260+25*i,40,20,20, "rgba(170,193,238,0.83)", "rgb(46,169,239)", 1);
}
// double loop for a grid
for(let i=0; i<5 ; i++){
    for(let j = 0; j<5; j++){
        drawRect(260+25*i,100+25*j,20,20, "rgba(170,193,238,0.83)", "rgb
   (46,169,239)", 1);
    }
}
```

Listing 5: Python example

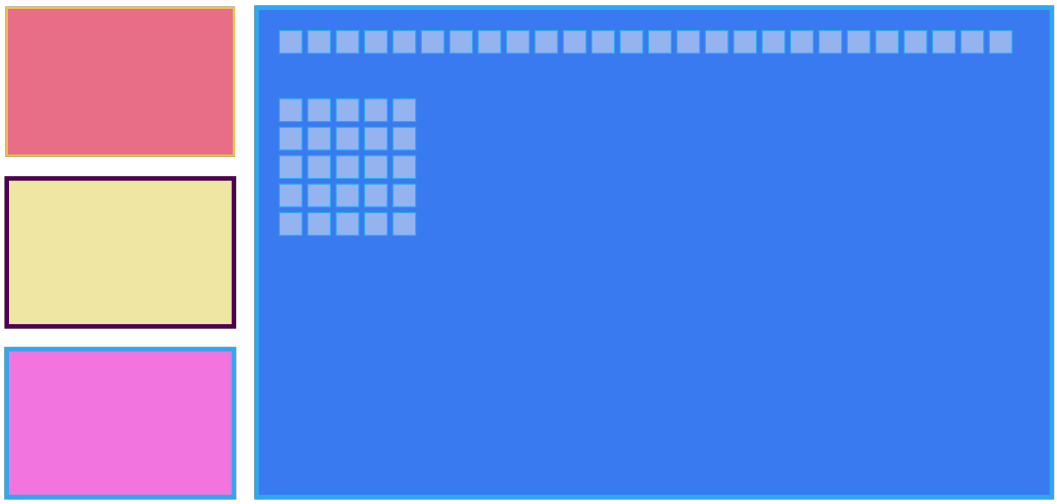


Figure 2: Canvas in browser

Design Functions for:

- Circle
- Line
- Triangle
- Square
- A Grid

- Text Box

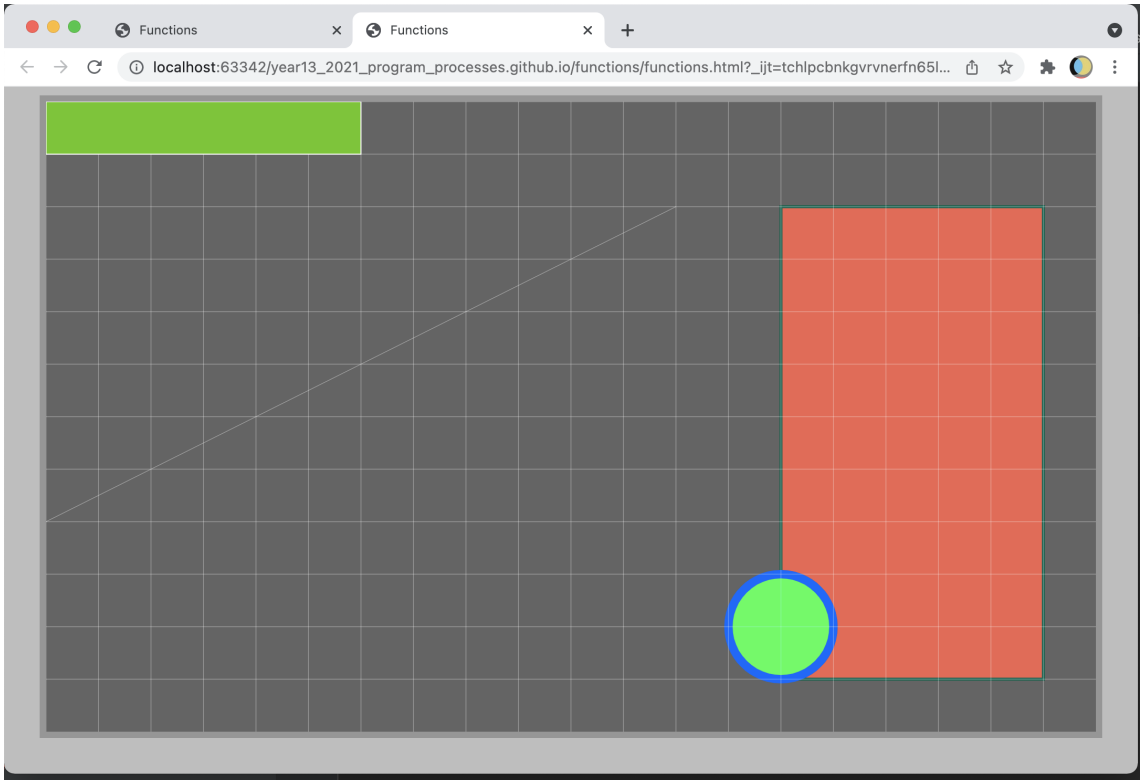


Figure 3: Canvas in browser

6 Making a grid

7 Update Context Function

We want to reduce code repetition as much as much as possible.
It might be an idea to have a small function to manage the fill and stroke commands.// This 'update context' function can sit near the top of the code and then be called from each of the shape drawing functions.

```
function updateContext(fillColour, strokeColour, strokeWidth){
    ctx.fillStyle = fillColour;
    ctx.strokeStyle = strokeColour;
    ctx.lineWidth = strokeWidth;
    if(fillColour){
        ctx.fill();
    }
    if(strokeColour|| strokeWidth){
        ctx.stroke();
    }
}
/**
 * Draw a rectangle
 *
 * @param {number} x corner x
 * @param {number} y corner y
 * @param {number} w width
 * @param {number} h height
 * @param {string} fillColour rgb string
 * @param {string} strokeColour rgb string.
 * @param {number} strokeWidth
 * @return {null}
 */
function drawRectangle(x,y,w,h, fillColour, strokeColour, strokeWidth){
    ctx.beginPath();
    ctx.rect(x,y,w,h);
    updateContext(fillColour, strokeColour, strokeWidth)
}
```

Listing 6: Loading javascript

8 Colour management

Rather than writing the rgb strings all of the time, it might be helpful to start a little colour management data structure.

The structure below is actually a simple JavaScript object. But at this stage we can treat much like a Python dictionary.

It has a keyword and an associated value.

```
// two dimensional array of colours
const col= [
[ // opaque
// black (0)                grey (1)                white (2)
"rgba(0,0,0,1)" , "rgba(150,150,150,1)", "rgba(255,255,255,1)" ,
// pink  (3)            purple (4)        deep blue (5)
"rgb(243,92,155,1)", "rgb(153,19,206,1)", "rgb(16,16,162,1)",
// pale blue (6)            yellow   (7)          bright yellow (7)
"rgba(135,211,243,1)", "rgba(246,244,193,1)", "rgba(250,250,0,1)"
],
[ // semi-transparent
// black (0)                grey (1)                white (2)
"rgba(0,0,0,0.5)" , "rgba(150,150,150,0.5)", "rgba(255,255,255,0.5)" ,
// pink  (3)            purple (4)        deep blue (5)
"rgb(243,92,155,0.5)", "rgb(153,19,206,0.5)", "rgb(16,16,162,0.5)",
// pale blue (6)            yellow   (7)          bright yellow (7)
"rgba(135,211,243,1,0.5)", "rgba(246,244,193,1,0.5)", "rgba(250,250,0,0.5)"
]
    ]
```

We can see its use in the function calls below

```
 * Draw a rectangle
 *
 * @param {number} x corner x
 * @param {number} y corner y
```

9 Organising an init file

We probably want to use the functions in various projects (subject to modifications).
We also have the set up code.
It might be a good idea to assemble this into a separate "initialisation" file (aka init.js). We could then have a separate file that does the "doing" of the program. We can load the files separately into the html document.

```
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <meta http-equiv="X-UA-Compatible" content="ie=edge">
    <title>Functions Collection</title>
</head>
<body>
<canvas id='myCanvas'></canvas>
<script type="text/javascript" src="init.js"> </script>
<script type="text/javascript" src="interface.js"> </script>
</body>
</html>
```

Listing 7: Loading javascript

```
drawRectangle(20,20,200,130, col[0][3], undefined, undefined);
drawRectangle(20,170,200,130, undefined, col[1][6], 9);
drawRectangle(20,320,200,130, col[0][3], col[0][6], 4);
drawRectangle(240,20,700,430,undefined,col[0][6], 4);

drawCircle(590, 235, 100, col[0][7], col[1][0], 10)

drawLine(240,450, 940,20, col[0][2], 1);
drawLine(240,20, 940,450, col[0][2], 1);
let x= 50
let space = 300
drawTextBox(x, 480, 260,"Button One", col[0][2],col[0][5]);
drawTextBox(x+space, 480, 260,"Button Two", col[0][2],col[0][5]);
drawTextBox(x+2*space, 480, 260,"Button Three", col[0][2],col[0][5]);
```

Listing 8: Loading javascript

```
canvas = document.querySelector('#myCanvas');
let ctx = canvas.getContext('2d');
// define width and height
let width = 1000;
let height = 600;
// define scale of 1. This may be changed later to improve resolution
```

```
let scale = 2;
// set the canvas width and height
canvas.width = width*scale;
canvas.height = height*scale;
// scale the canvas
ctx.scale(scale,scale);
// get the canvas element
// style it here so it will be consistent
let my_c = document.getElementById('myCanvas');
my_c.style.backgroundColor = "rgb(100,100,100)"
my_c.style.width = width+"px";
my_c.style.height = height+"px";
my_c.style.border = "6px solid rgba(200,200,200,0.5)";
my_c.style.display = "block";
my_c.style.margin = "auto";
document.body.style.backgroundColor = "rgb(190,190,190)";


// two dimensional array of colours
const col= [
    [ // opaque
// black (0)               grey (1)               white (2)
        "rgba(0,0,0,1)" , "rgba(150,150,150,1)", "rgba(255,255,255,1)" ,
// pink  (3)           purple (4)       deep blue (5)
        "rgb(243,92,155,1)", "rgb(153,19,206,1)", "rgb(16,16,162,1)",
// pale blue (6)           yellow   (7)         bright yellow (7)
        "rgba(135,211,243,1)", "rgba(246,244,193,1)", "rgba(250,250,0,1)"
    ],
    [ // semi-transparent
// black (0)               grey (1)               white (2)
        "rgba(0,0,0,0.5)" , "rgba(150,150,150,0.5)", "rgba(255,255,255,0.5)" ,
// pink  (3)           purple (4)       deep blue (5)
        "rgb(243,92,155,0.5)", "rgb(153,19,206,0.5)", "rgb(16,16,162,0.5)",
// pale blue (6)           yellow   (7)         bright yellow (7)
        "rgba(135,211,243,0.5)", "rgba(246,244,193,0.5)", "rgba(250,250,0,0.5)"
    ]
]
/**
 * Fill and or Stroke the Current Path
 *
 * @param {string} fillColour rgb string
 * @param {string} strokeColour rgb string.
 * @param {number} strokeWidth
 * @return {null}
 */
function updateContext(fillColour, strokeColour, strokeWidth){
    ctx.fillStyle = fillColour;
```

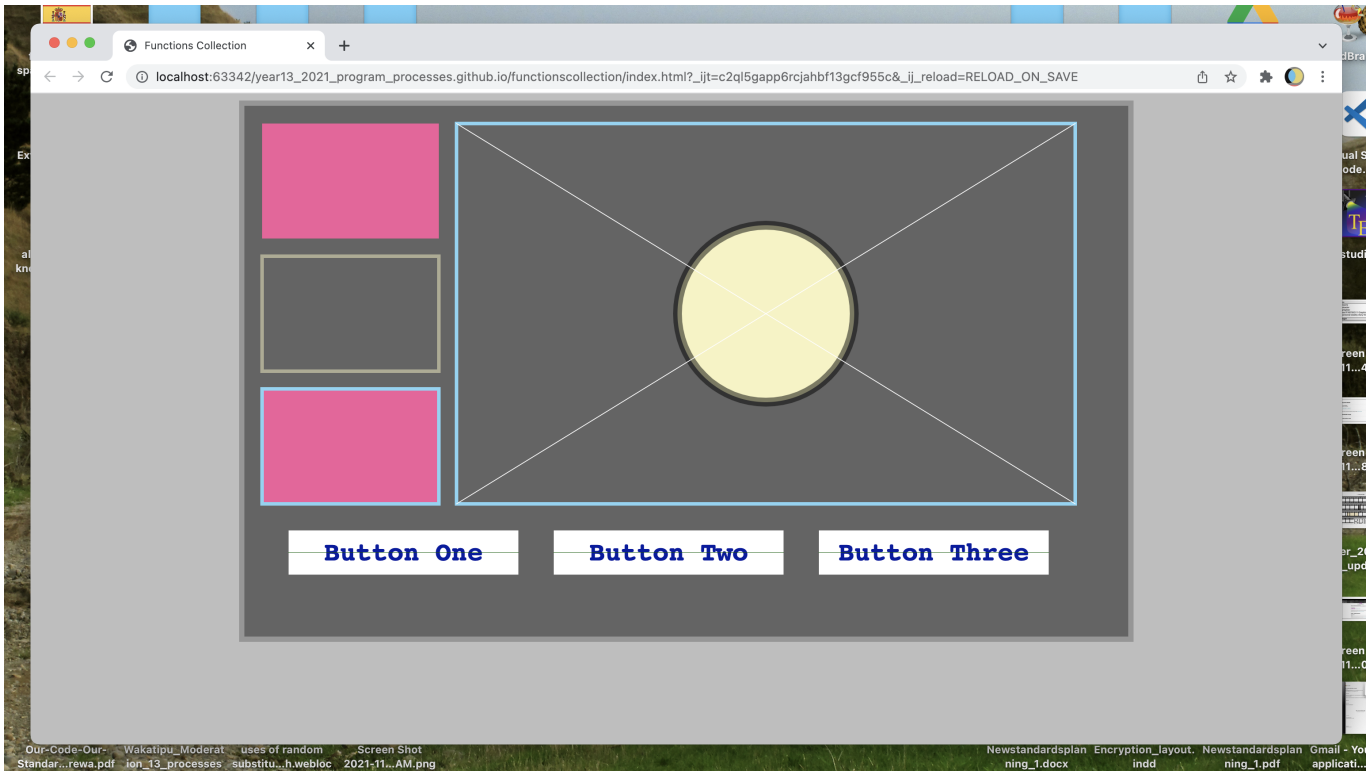
```
    ctx.strokeStyle = strokeColour;
    ctx.lineWidth = strokeWidth;
    if(fillColour){
        ctx.fill();
    }
    if(strokeColour|| strokeWidth){
        ctx.stroke();
    }
}
/**
 * Draw a rectangle
 *
 * @param {number} x corner x
 * @param {number} y corner y
 * @param {number} w width
 * @param {number} h height
 * @param {string} fillColour rgb string
 * @param {string} strokeColour rgb string.
 * @param {number} strokeWidth
 * @return {null}
 */
function drawRectangle(x,y,w,h, fillColour, strokeColour, strokeWidth){
    ctx.beginPath();
    ctx.rect(x,y,w,h);
    updateContext(fillColour, strokeColour, strokeWidth)
}
/**
 * Draw a circle
 *
 * @param {number} x centre x
 * @param {number} y centre y
 * @param {number} r radius
 * @param {string} fillColour rgb string
 * @param {string} strokeColour rgb string.
 * @param {number} strokeWidth
 * @return {null}
 */
function drawCircle(x,y,r,  fillColour, strokeColour, strokeWidth){
    ctx.beginPath();
    ctx.arc(x,y,r,0,2*Math.PI);
    updateContext(fillColour, strokeColour, strokeWidth)
}
/**
 * Draw a line
 *
    * @param {number} x_1 start x
    * @param {number} y_1 start y
```

```
    * @param {number} x_2 end x
    * @param {number} y_2 end y
    * @param {string} strokeColour rgb string.
    * @param {number} strokeWidth
    * @return {null}
 */
function drawLine(x_1,y_1, x_2, y_2, strokeColour,strokeWidth){
    ctx.beginPath();
    ctx.moveTo(x_1,y_1);
    ctx.lineTo(x_2,y_2);
    ctx.lineCap = "round";
    updateContext(undefined, strokeColour, strokeWidth);
}
/**
 * Draw text
    *
    * @param {number} x top corner x
    * @param {number} y top corner y
    * @param {string} txt
    * @param {string} fillColour rgb string.
    * @param {string} font css shorthand font style
    * @return {null}
 */
function drawText(txt ,x,y,fillColour, font = "bold 30px monospace" ) {
    ctx.font = font;
    ctx.fillStyle = fillColour;
    ctx.fillText(txt, x,y);
}
/**
 * Draw text box
    *
    * @param {number} x top corner x
    * @param {number} y top corner y
    * @param {number} w width
    * @param {string} txt
    * @param {string} backColour rgb string.
    * @param {string} fillColour rgb string.
    * @param {string} font css shorthand font style
    * @return {null}
 */
function drawTextBox(x,y,w,txt,backColour, fillColour, font = "bold 30px
   monospace"){
    let h = 50;
    drawRectangle(x,y,w,h, backColour, undefined, undefined)

    drawLine(x,y+h/2,x+w,y+h/2, col[0][4],1);
    ctx.textAlign = "center";
```

```
147     ctx.textBaseline = "middle";
148     drawText(txt, x+w/2,y+h/2, fillColour);
149 }
```

Listing 9: Loading javascript



10 Rotations

11 Objects

We are intending to introduce animation into our canvas environment.
To do so we will need to create objects.
At present, it will appear to serve no new purpose, so please be patient. Just about everything we make will be object based from now on.
Diagram

```
// init file with canvas set up
// colours
// functions
//...
```

Listing 10: Init file (not shown)

```
/**
 * Filled Ball
 * @param {number} x top corner of bounding box
 * @param {number} y top corner of bounding box
 * @param {string} fill fill colour
 * @param {string} stroke stroke colour
 * @param {number} strokeWidth  width of outline
 */
class Ball{
    constructor(x,y,r,fill, stroke, strokeWidth){
        this.x = x;
        this.y = y;
        this.r=r;
        this.fill=fill;
        this.stroke = stroke;
        this.strokeWidth = strokeWidth;
    }
    update(){
        this.draw()
    }
    draw(){
        this.drawCircle(this.x, this.y, this.r, this.fill, this.stroke, this.
   strokeWidth)
    }
}
Ball.prototype.drawCircle = drawCircle
Ball.prototype.updateContext = updateContext

/**
 * Filled Rectangle
 * @param {number} x top corner of bounding box
```

```
 * @param {number} y top corner of bounding box
 * @param {number} w width
 * @param {number} h height
 * @param {string} fill fill colour
 * @param {string} stroke stroke colour
 * @param {number} strokeWidth  width of outline
 */
class Rectangle{
    constructor(x,y,w,h,fill, stroke, strokeWidth){
        this.x = x;
        this.y = y;
        this.w=w;
        this.h=h;
        this.fill=fill;
        this.stroke = stroke;
        this.strokeWidth = strokeWidth;
    }
    update(){
        this.draw()
    }
    draw(){
        this.drawRectangle(this.x, this.y, this.w, this.h, this.fill, this.stroke
    , this.strokeWidth)
    }
}
Rectangle.prototype.drawRectangle = drawRectangle
Rectangle.prototype.updateContext = updateContext
/**
 * Filled TextBox
 * @param {number} x top corner of bounding box
 * @param {number} y top corner of bounding box
 * @param {number} w width
 * @param {string} txt text
 * @param {string} fill fill colour
 * @param {string} txtColour colour of text
 */
class TextBox{
    constructor(x,y,width,txt, fillColour, txtColour) {
        this.x = x;
        this.y = y;
        this.w = width;
        this.txt = txt;
        this.fillColour = fillColour;
        this.txtColour = txtColour;
    }
    update(txt){
        this.txt = txt
```

```
77          this.draw()
78      }
79
80      draw(){
81          this.drawTextBox(this.x, this.y,this.w,this.txt, this.fillColour, this.
    txtColour)
82
83      }
84  }
85  TextBox.prototype.drawTextBox = drawTextBox;
86
87
88  /**
89   * Grid - square grid
90   * @param {number} w width of canvas
91   * @param {number} h height of canvas
92   * @param {number} intervalWidth height of canvas
93   * @param {string} strokeColour stroke colour
94   * @param {number} strokeWidth  width of outline
95   */
96  class Grid{
97      constructor(w,h,intervalWidth, strokeColour, strokeWidth){
98          this.w = w;
99          this.h = h;
100         this.intervalWidth=intervalWidth;
101         this.strokeColour = strokeColour;
102         this.strokeWidth = strokeWidth;
103     }
104     update(){
105         this.draw()
106     }
107     draw(){
108
109         for(let i = -this.w ; i <= this.w ; i+= this.intervalWidth){
110
111             this.drawLine(i,-this.h, i,this.h, this.strokeColour, this.
    strokeWidth);
112         }
113         for(let j = -this.h ; j <= this.h ; j+= this.intervalWidth){
114             this.drawLine(-this.w,j, this.w,j, this.strokeColour, this.
    strokeWidth);
115         }
116         this.drawCircle(0,0,20,undefined,col[0][4], 5);
117         this.drawLine(-this.w,0, this.w, 0, col[0][4], 4);
118         this.drawLine(0, -this.h, 0, this.h, col[0][4], 4);
119     }
120 }
```

```
Grid.prototype.drawCircle = drawCircle
Grid.prototype.drawLine = drawLine
Grid.prototype.updateContext = updateContext
```

Listing 11: objectSet file

```
<canvas id='myCanvas'></canvas>
<script type="text/javascript" src="init.js"> </script>
<script type="text/javascript" src="objectSet.js"> </script>
<script>



    let G= new Grid(width, height, 100, col[0][2], 0.5);
    let R = new Rectangle(-50,-25,100,50, col[0][6], undefined, undefined)

    G.update();
    ctx.save();
    ctx.translate(500,300);
    ctx.rotate(60*Math.PI/180);
    //G.update();
    R.update();
    ctx.restore()

    ballSet = []
    let r = 20
    let x = 100
    let y = 400
    let space = 5*r
    for(let i= 0; i< col[0].length; i++){
        let temp = new Ball(x+ space*i, y, r , col[0][i], col[0][5], 2)
        ballSet.push(temp)

    }
    console.log(ballSet)
    for(let j=0; j<ballSet.length; j++){
        ballSet[j].update()
    }

    let T = new TextBox(100,100,150, "", col[0][1], col[0][2])
    T.update("5")
```

Listing 12: Implementing (using HTML file)

12 Animation Frame

Set up code

```
// init file with canvas set up
// colours
// functions
//...
canvas = document.querySelector('#myCanvas');
let ctx = canvas.getContext('2d');
// define width and height
let width = 1000;
let height = 600;
// define scale of 1. This may be changed later to improve resolution
let scale = 2;
// set the canvas width and height
canvas.width = width*scale;
canvas.height = height*scale;
// scale the canvas
ctx.scale(scale,scale);
// get the canvas element
// style it here so it will be consistent
let my_c = document.getElementById('myCanvas');
my_c.style.backgroundColor = "rgb(100,100,100)"
my_c.style.width = width+"px";
my_c.style.height = height+"px";
my_c.style.border = "6px solid rgba(200,200,200,0.5)";
my_c.style.display = "block";
my_c.style.margin = "auto";
document.body.style.backgroundColor = "rgb(190,190,190)";


// two dimensional array of colours
const col= [
    [ // opaque
// black (0)               grey (1)               white (2)
        "rgba(0,0,0,1)" , "rgba(150,150,150,1)", "rgba(255,255,255,1)" ,
// pink  (3)           purple (4)       deep blue (5)
        "rgb(243,92,155,1)", "rgb(153,19,206,1)", "rgb(16,16,162,1)",
// pale blue (6)           yellow   (7)         bright yellow (7)
        "rgba(135,211,243,1)", "rgba(246,244,193,1)", "rgba(250,250,0,1)"
    ],
    [ // semi-transparent
// black (0)               grey (1)               white (2)
        "rgba(0,0,0,0.5)" , "rgba(150,150,150,0.5)", "rgba(255,255,255,0.5)" ,
// pink  (3)           purple (4)       deep blue (5)
        "rgb(243,92,155,0.5)", "rgb(153,19,206,0.5)", "rgb(16,16,162,0.5)",
```

```
// pale blue (6)            yellow   (7)          bright yellow (7)
        "rgba(135,211,243,0.5)", "rgba(246,244,193,0.5)", "rgba(250,250,0,0.5)"
    ]
]
```

Listing 13: init

```
/**
 * Grid - square grid
 * @param {number} w width of canvas
 * @param {number} h height of canvas
 * @param {number} intervalWidth distance each grid unit
 * @param {string} strokeColour stroke colour
 * @param {number} strokeWidth  width of outline
 */
class Grid{
    constructor(w,h,intervalWidth, strokeColour, strokeWidth){
        this.w = w;
        this.h = h;
        this.intervalWidth=intervalWidth;
        this.strokeColour = strokeColour;
        this.strokeWidth = strokeWidth;
    }
    update(){
        this.draw()
    }
    draw(){
        for(let i = -this.w ; i <= this.w ; i+= this.intervalWidth){
            this.drawLine(i,-this.h, i,this.h, this.strokeColour, this.
    strokeWidth);
        }

        for(let j = -this.h ; j <= this.h ; j+= this.intervalWidth){
            this.drawLine(-this.w,j, this.w,j, this.strokeColour, this.
    strokeWidth);
        }

    }

    drawLine(x_1,y_1, x_2, y_2, strokeColour,strokeWidth){
        ctx.beginPath();
        ctx.moveTo(x_1,y_1);
        ctx.lineTo(x_2,y_2);
        ctx.lineCap = "round";
        ctx.strokeStyle = strokeColour;
        ctx.lineWidth = strokeWidth;
        ctx .stroke()
    }
```

```
}

/**
 * Filled TextBox
 * @param {number} x top corner of bounding box
 * @param {number} y top corner of bounding box
 * @param {number} w width
 * @param {string} txt text
 * @param {string} fill fill colour
 * @param {string} txtColour colour of text
 */
class TextBox{
    constructor(x,y,width, fillColour, txtColour) {
        this.x = x;
        this.y = y;
        this.w = width;
        // fixed height
        this.h = 50;
        // text managed through update
        this.txt = "Placeholder";
        console.log(this.txt)
        this.fillColour = fillColour;
        this.txtColour = txtColour;
    }
    update(txt ="Placeholder"){
        this.txt = txt
        this.draw()
    }

    draw(){
        ctx.beginPath();
        ctx.rect(this.x,this.y,this.w,this.h);
        ctx.fillStyle= this.fillColour;
        ctx.fill();
        ctx.font = "20px monospace";
        ctx.textAlign = "center";
        ctx.textBaseline = "middle";
        ctx.fillStyle = this.txtColour;
        ctx.fillText(this.txt, this.x+this.w/2, this.y+this.h/2);
    }
}
```

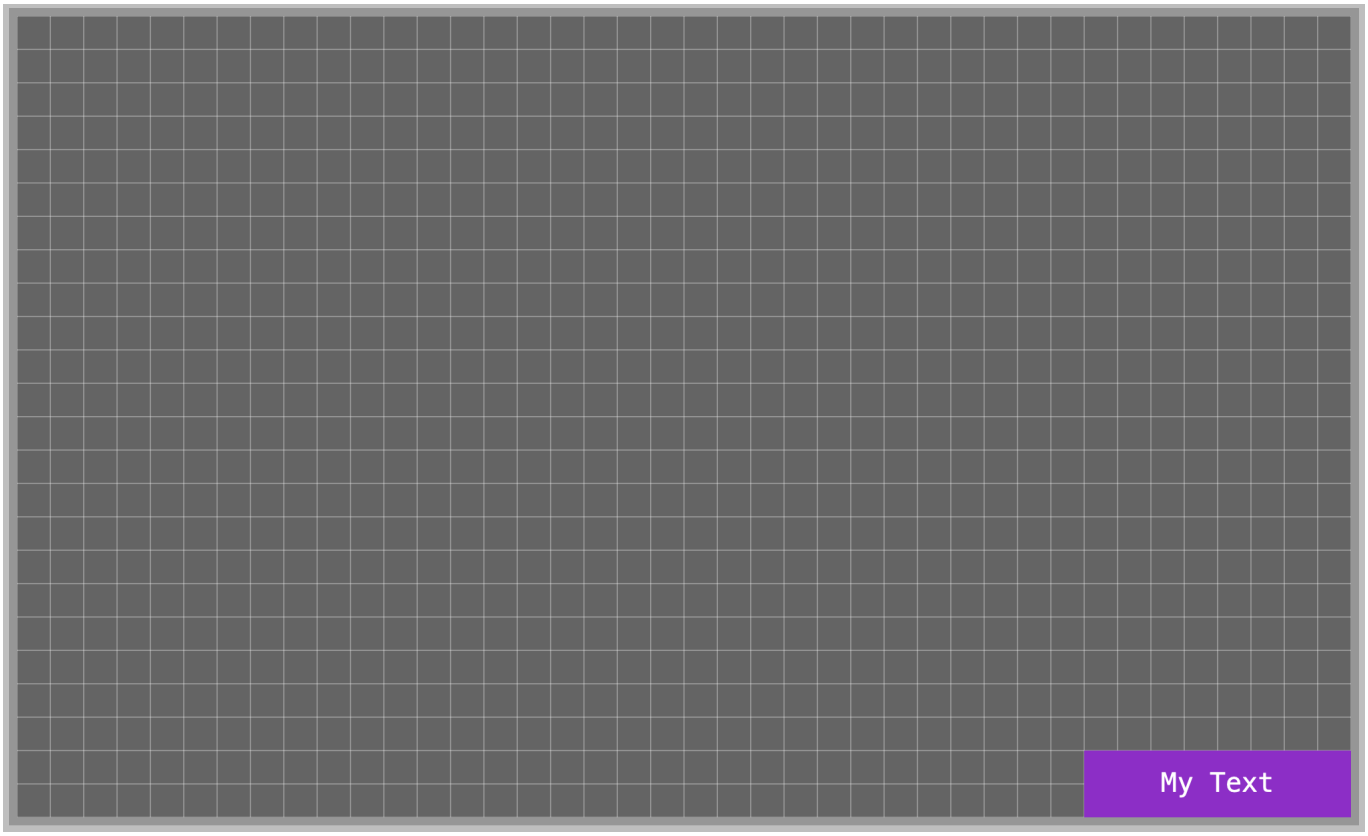
Listing 14: objects

```
<!DOCTYPE html>
<html lang="en">
<head>
  <meta charset="UTF-8">
```

```
  <meta name="viewport" content="width=device-width, initial-scale=1.0">
  <meta http-equiv="X-UA-Compatible" content="ie=edge">
  <title>Objects Start</title>
</head>
<body>
<canvas id='myCanvas'></canvas>
<script type="text/javascript" src="init.js"> </script>
<script type="text/javascript" src="objects.js"> </script>
<script>
  let G = new Grid(width, height, 25, col[0][2], 0.3)
  let T = new TextBox(800,550,200, col[0][4], col[0][2])
  G.update();
  // note that the text is set through the update function call
  T.update("My Text");

</script>
</body>
</html>
```

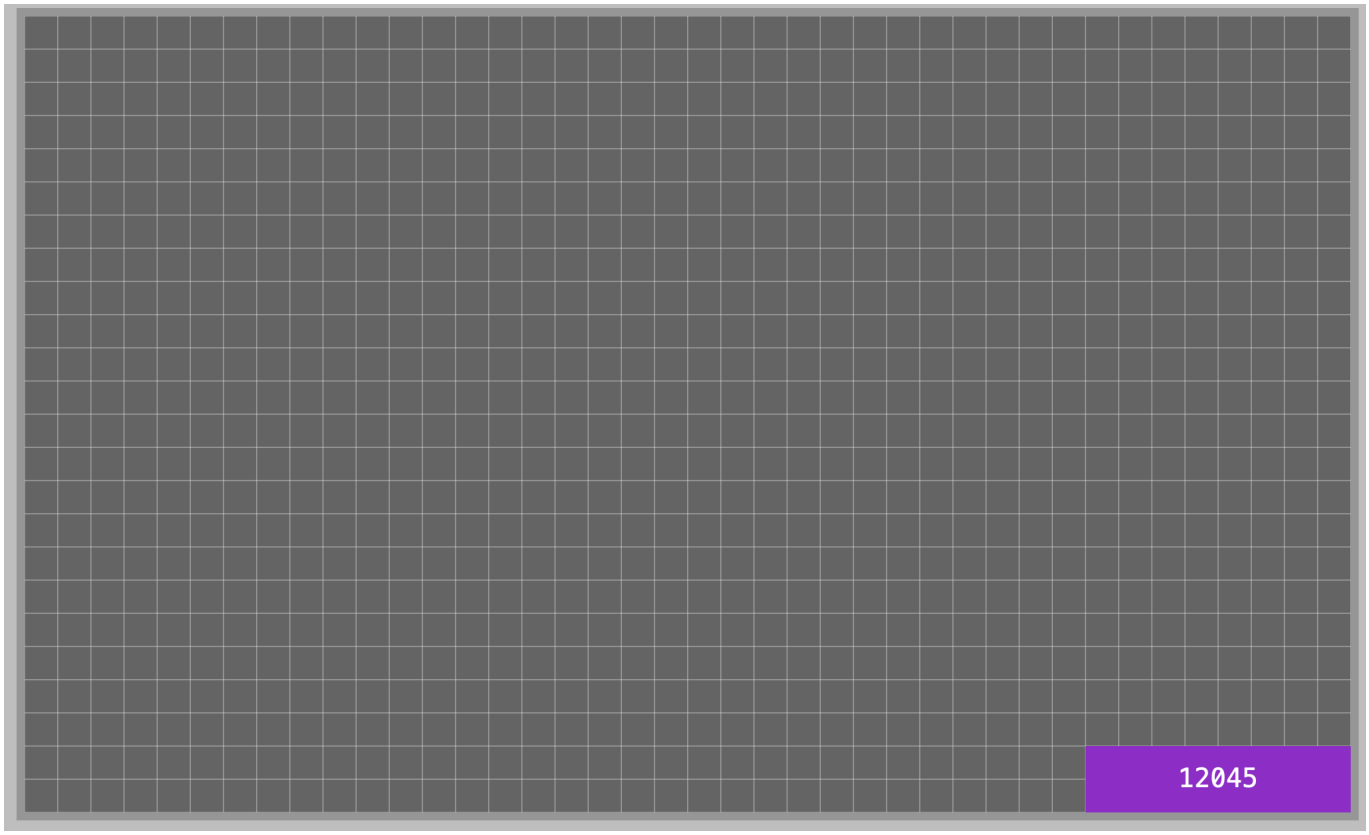
Listing 15: index




```
<script>
  let G = new Grid(width, height, 25, col[0][2], 0.3)
  let T = new TextBox(800,550,200, col[0][4], col[0][2])
  // create an animation function
  function animate(t){
```

```
    ctx.clearRect(0,0, width, height);
    G.update();
    let timer = Math.round(t)
    T.update(timer);
    // the call below is a request to the browser
    // the function is called again (about 50 times a second)
    window.requestAnimationFrame(animate)
  }
  // start off call to get it going
  animate()
</script>
```

Listing 16: index

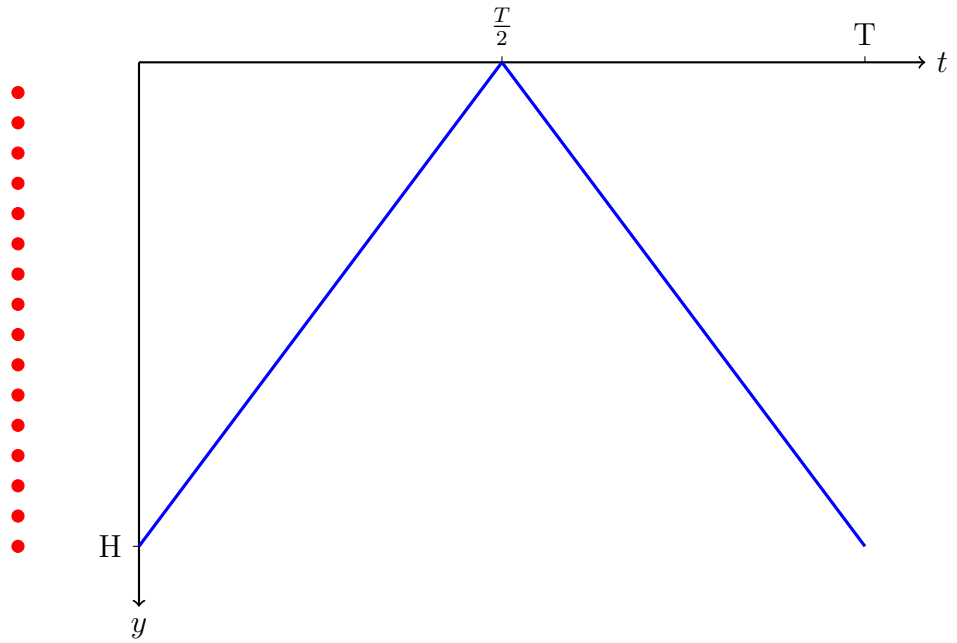


13 Animation

13.1 Linear Interpolation

Consider the graph below.
The graph runs of a interval of T and moves between a maximum height of H and a minimum of 0.
We could use this to represent a, very simple, motion of a ball going up and down.
If we keep repeating the interval, the ball would go up and don indefinitely.
The lower case t represents the 'time ticks' and is like the x value.
The equations for this piecewise graph are given below and you should be able to work these out for yourself.

The graph has been drawn upside down, so it is like the canvas co-ordinate system



$$\begin{cases} y = \dfrac{-2Ht}{T} + H \quad , \quad 0 < t \leq \dfrac{T}{2} \\ \\ y = \dfrac{2Ht}{T} - H \quad , \quad \dfrac{T}{2} < x \leq T \end{cases}$$

We have an animation frame that runs at somewhere between 40 and 60 time ticks per second.
So we should be able to implement the functions given about and update the t value, for every tick of the animation frame.

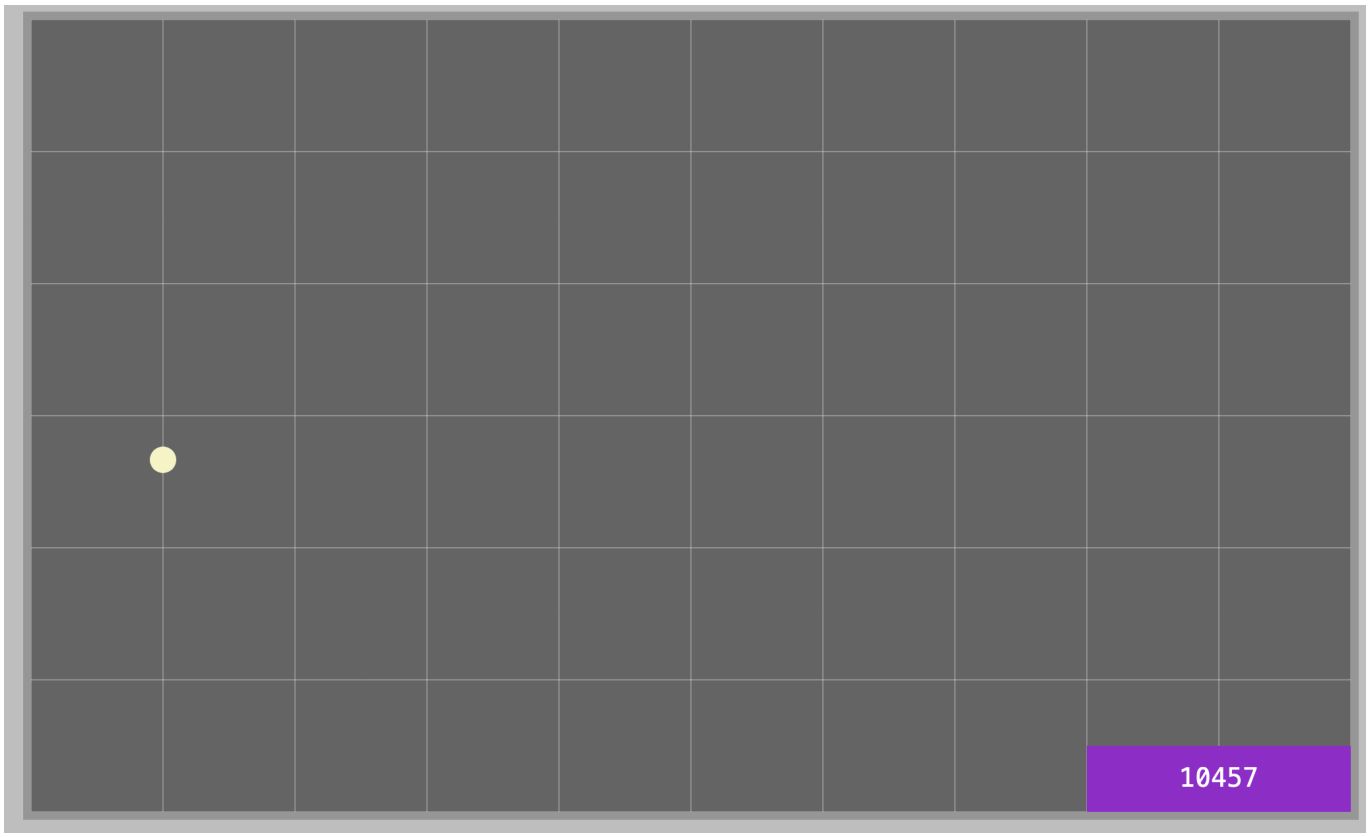
Moving Ball Object

```
/**
 * Ball that moves up down
 * @param {number} x_b base x position
 * @param {number} y_b base y position
 * @param {number} radius radius
 * @param {string} fillColour fill colour
 * @param {number} T total Tick interval (50 ticks = about 1 second)
 * @param {number} H total Height covered by up/down motion
 */
class MovingBall{
    constructor(x_b,y_b,r, fillcolour, T, H){
        this.x_b = x_b;
        this.y_b = y_b;
        this.r = r;
        this.fillColour = fillcolour;
        // animation variables
        this.t = 0;
        this.T = T;
        this.H = H;
    }
    update(){
        // add one to the value of little t each time update is called
        this.t +=1
        this.draw()
    }
    draw(){
        // get y value from the piecewise function
        let y = this.linearinterpolate(this.t, this.T, this.H)
        this.drawCircle(this.x_b,y+this.y_b, this.r)
    }

    linearinterpolate(t,T,H){
        // takes parameter t , T, H
        // we could hard code in this.T etc but is more fexible to have
   parameters
        // make sure t is between 0 and T
        t = t%T;  // modulus operator
        // set y variable and use to get value from equations
        let y;
        if(t<T/2){
            y = (-2*H*t)/(T) + H
        }else{
            y = (2*H*t)/(T) - H
        }
        return y
```

```
45      }
46      drawCircle(x,y,r){
47          ctx.beginPath()
48          ctx.arc(x, y, r, 0, 2*Math.PI)
49          ctx.fillStyle = this.fillColour
50          ctx.fill();
51      }
```

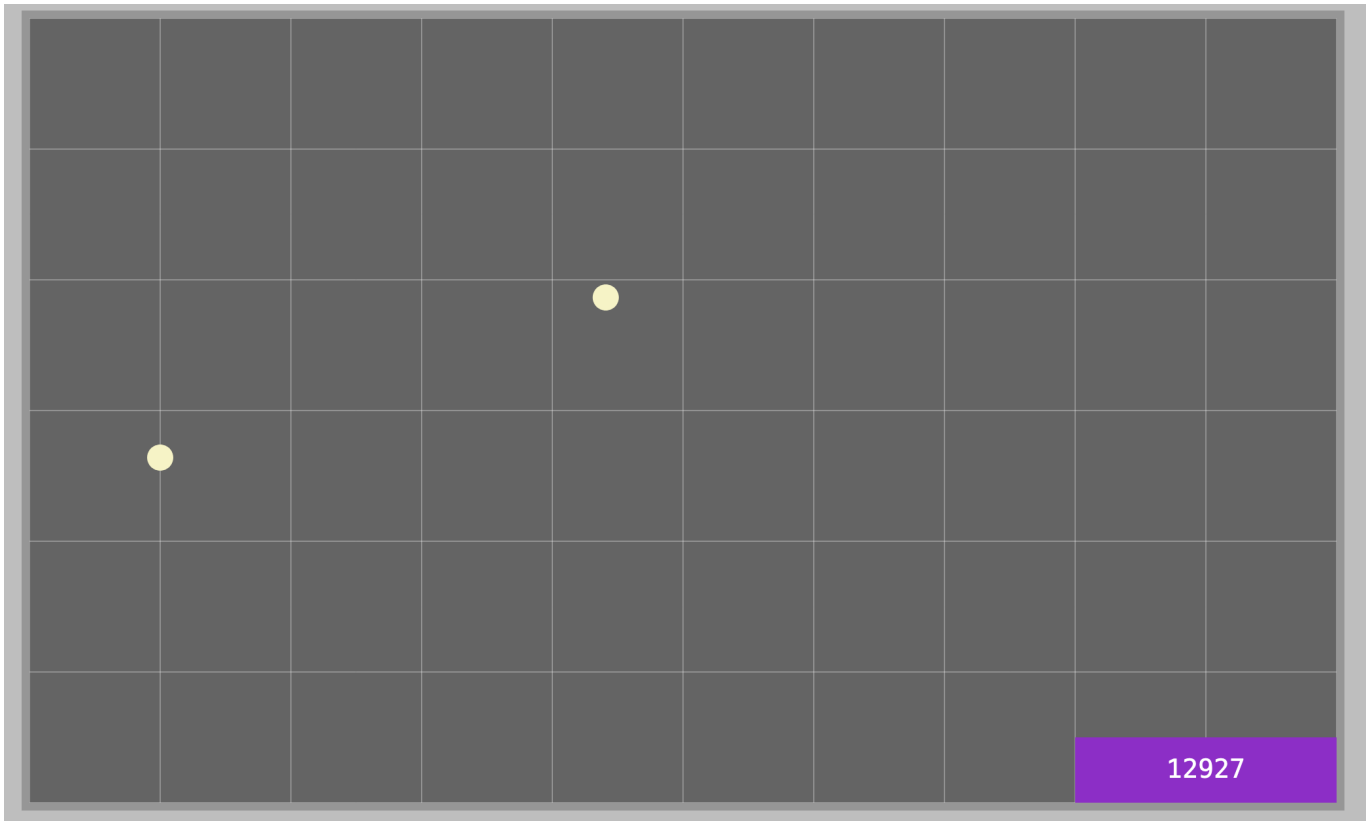
Listing 17: Moving Ball



We can introduce left right motion.

```
 */
class MovingBallBoth{
    constructor(x_b,y_b,r, fillcolour, T, H, xIS){
        this.x_b = x_b;
        this.y_b = y_b;
        this.r = r;
        this.fillColour = fillcolour;
        // animation variables
        // set a random starting point (while be helpful when we have lots of moving balls)
        this.t = T*Math.random();
        this.T = T;
        this.H = H;
        // introduce an interval shift for the x interval
        // this will make the ball behave more naturalistically
        this.xIntervalShift = xIS
    }
    update(){
        // add one to the value of little t each time update is called
        this.t +=1
        this.draw()
    }
    draw(){
        // get y value from the piecewise function
        let y = this.linearinterpolate(this.t, this.T, this.H)
        // the interval is multiplied by the x interval shift
        let x = this.linearinterpolate(this.t, this.T*this.xIntervalShift, this.H)
        this.drawCircle(x+this.x_b,y+this.y_b, this.r)
```

Listing 18: Part of Bothways Moving Ball

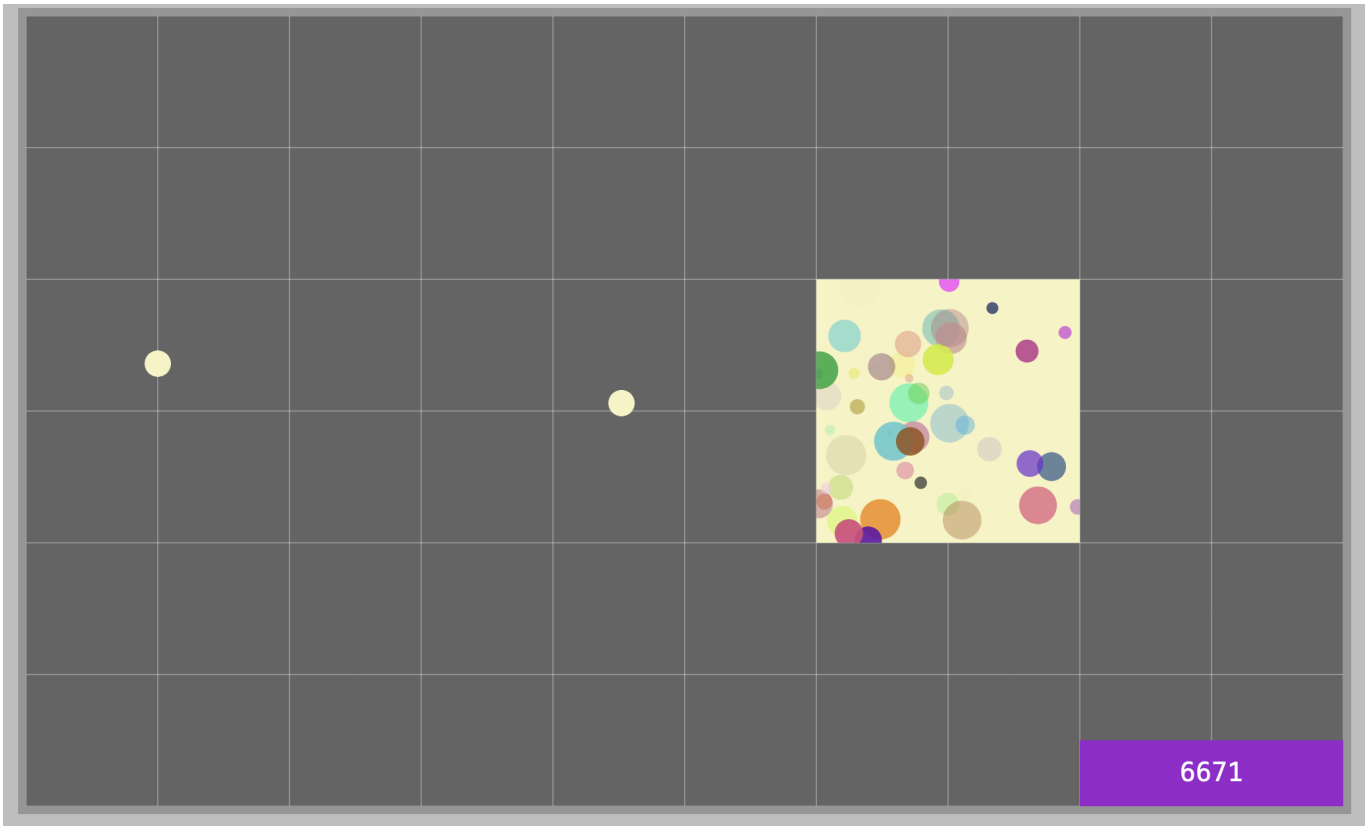

12927

Introduce a whole group (or field) of moving balls.

```
/**
 * Ball that moves up down
 * @param {number} x_b base x position
 * @param {number} y_b base y position
 * @param {number} radius radius
 * @param {string} fillColour fill colour
 * @param {number} T total Tick interval (50 ticks = about 1 second)
 * @param {number} H total Height covered by up/down motion
 */
class BallGroup{
    constructor(x_b,y_b,r, fillColour, T, H){
        this.x_b = x_b
        this.y_b = y_b
        this.H = H
        this.fillColour = fillColour
        // create a list that is going to hold a whole set of ball objects
        this.BSet = []
        //run a loop (in this case x50)
        for(let i=0; i<50; i++){
            // randomly set the amount of x interval shift
            let xIS = 1+5*Math.random()
            // randomly adjust the interval
            let randT = T + 2*T*Math.random()
            // create random red, green, blue
            let red = 255*Math.random();
            let green = 255*Math.random();
            let blue = 255*Math.random();
            // create random transparency
            let alpha = Math.random();
            // concatenate to make a rgb string
            let randColour = "rgba("+ red + ","+ green + "," + blue + "," + alpha
    +")"
            // randomly adjust the radius size
            let radius = r*7*Math.random()+r
            // create a moving ball using these values
            let temp = new MovingBallBoth(x_b,y_b,radius, randColour, randT, H,
   xIS)
            // push it into the BSet list
            this.BSet.push(temp)
        }
    }
    update(){
        // this is an extra bit
        // save the canvas
```

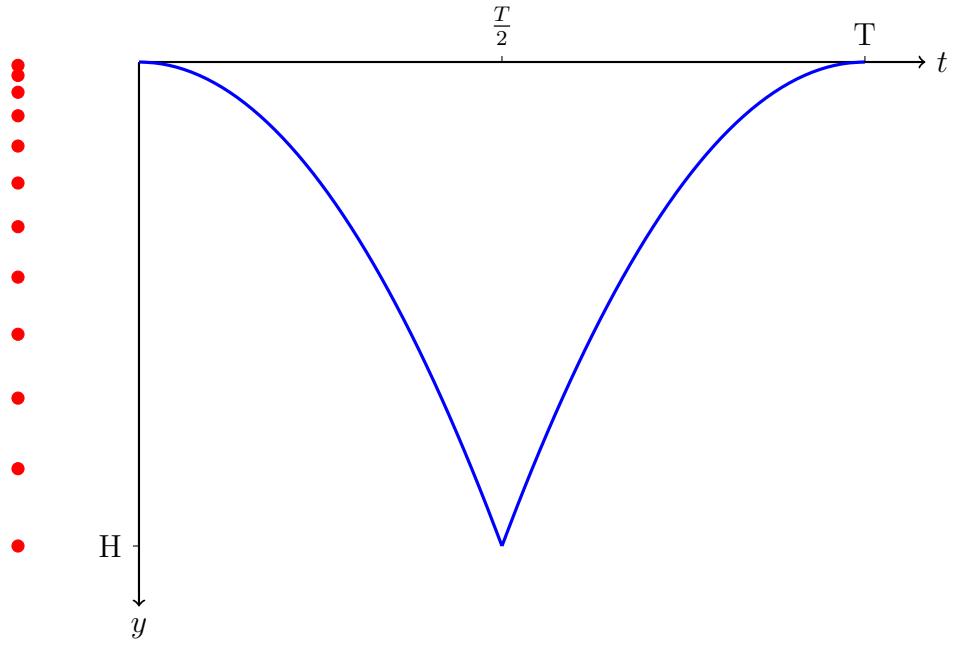
```
        ctx.save()
        // draw and fill a background rectangle
        this.drawRect(this.x_b, this.y_b, this.H, this.H)
        // the clip method will "clip out" anything outside the rectangle
        ctx.clip()
        // run a loop through the BSet
        for(let i=0; i<this.BSet.length ; i++){
            // call update on each moving ball
            this.BSet[i].update()
        }
        // restore the context (this removes the clip)
        ctx.restore()
```

Listing 19: Field of moving balls



13.2 Quadratic Interpolation

We can follow the same idea using parabolas:



$$\begin{cases} y = \dfrac{4Ht^2}{T^2} \quad , & 0 < t \leq \dfrac{T}{2} \\ y = \dfrac{4H(t-T)^2}{T^2} \quad , & \dfrac{T}{2} < x \leq T \end{cases}$$

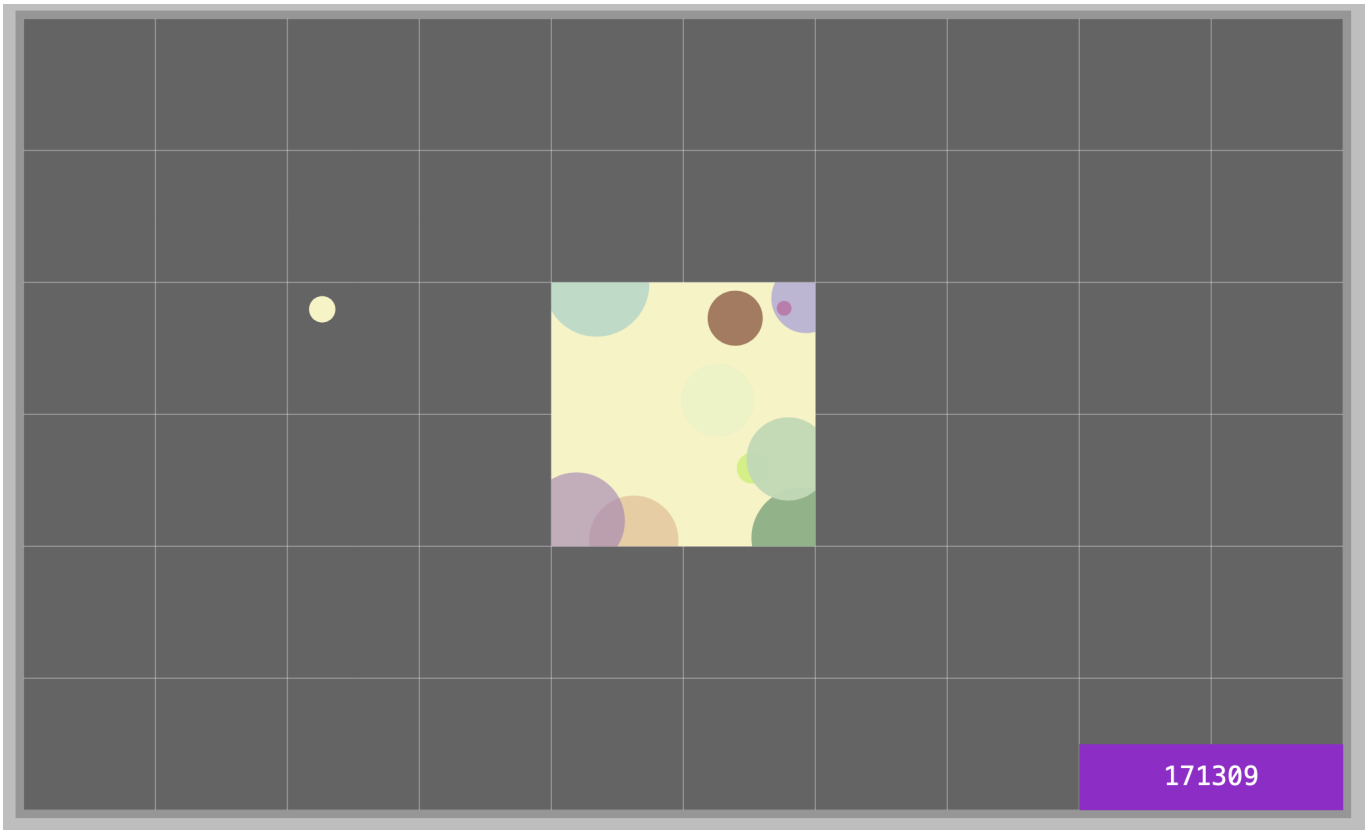
In this case, we would have the up down motion as quadratic, and the the left right as linear.

Below is the code for a Quadratic Ball Class.
Notice how short it is. What's going on here?

```
class QuadraticBall extends MovingBallBoth{
    draw(){
        // get y value from the piecewise function
        let y = this.quadraticInterpolate(this.t, this.T, this.H)
        // the interval is multiplied by the x interval shift
        let x = this.linearinterpolate(this.t +this.T*this.xIntervalShift/2, this
    .T*this.xIntervalShift, this.H)
        this.drawCircle(x+this.x_b,y+this.y_b, this.r)
    }
    quadraticInterpolate(t,T,H){
        // takes parameter t , T, H
        // we could hard code in this.T etc but is more fexible to have
    parameters
        // make sure t is between 0 and T
        t = t%T;  // modulus operator
        // set y variable and use to get value from equations
```

```
        let y;
        if(t<T/2){
            y = ( 4*H*Math.pow(t,2) )/( Math.pow(T,2) )
        }else{
            y = ( 4*H*Math.pow(t-T,2) )/( Math.pow(T,2) )
        }
        return y
    }
}
```

Listing 20: Quadratic Ball Class



A small rewrite has been done on the QuadraticBallGroup Class.

This will mean it can be extended in the next section.

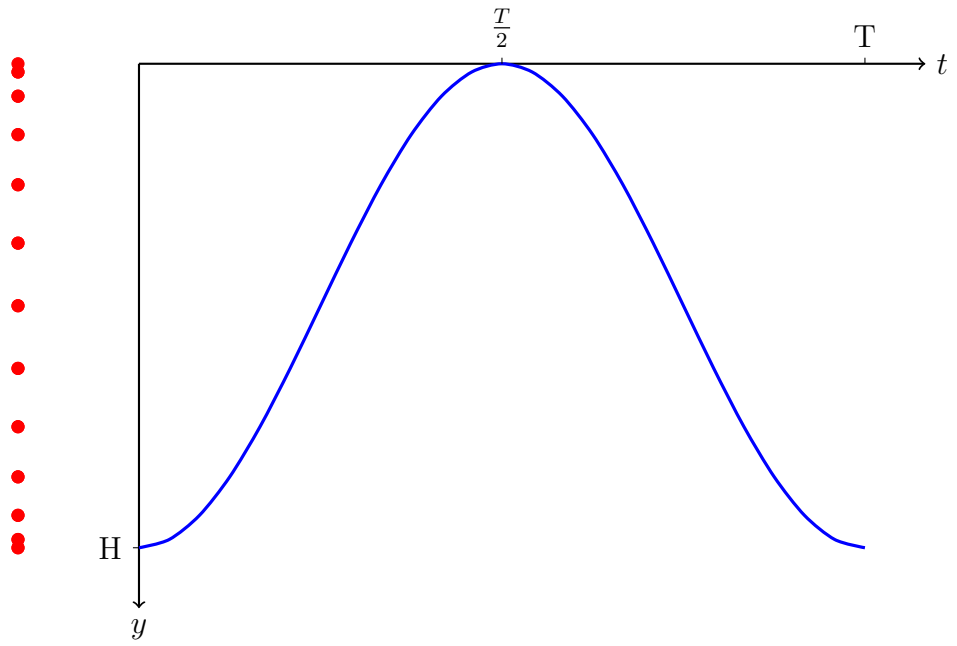
```
            let radius = r*10*Math.random()+r
            // create a moving ball using these values
            let temp = this.getObject(x_b,y_b,radius, randColour, randT, H, xIS)
            // push it into the BSet list
            this.BSet.push(temp)
        }
    }
    getObject(x_b,y_b,radius, randColour, randT, H, xIS){
        return  new QuadraticBall(x_b,y_b,radius, randColour, randT, H, xIS)
    }
```

```
11      update(){
```

Listing 21: Quadratic Ball Class

13.3 Trigonometric Interpolation

We can follow the same idea using parabolas:



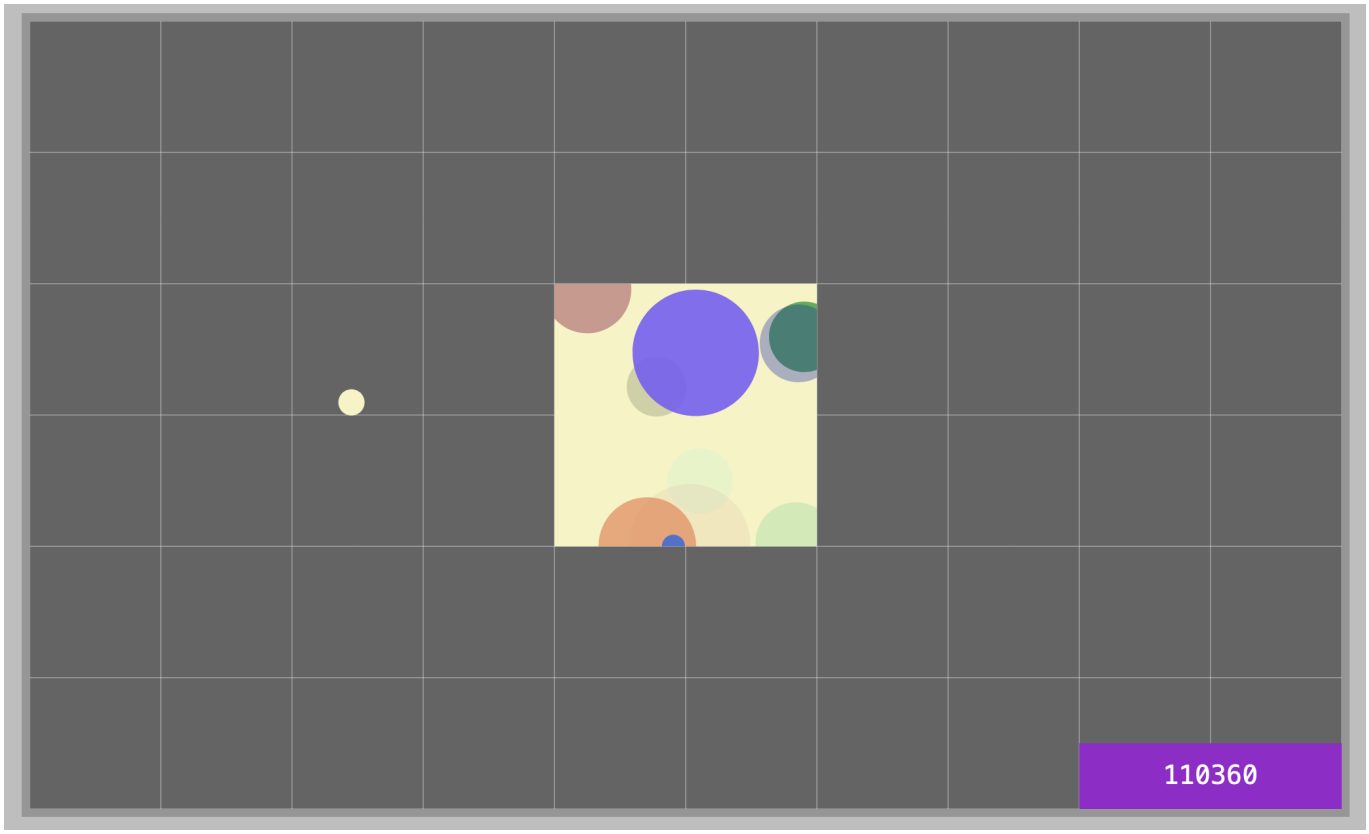
$$y = \frac{H}{2}\cos(\frac{2\pi}{T}t) + \frac{H}{2}$$

Complete code for both the TrigBall class and TrigBallGroup class (both are inheriting from the class referred to in the extension).

```
/**
 * Ball that moves trigonometrically
 * @param {number} x_b base x position
 * @param {number} y_b base y position
 * @param {number} radius radius
 * @param {string} fillColour fill colour
 * @param {number} T total Tick interval (50 ticks = about 1 second)
 * @param {number} H total Height covered by up/down motion
 * @param {number} xIS x interval shift (to make a different interval for left
   right movement
 */
class TrigBall extends MovingBallBoth{
    draw(){
        // get y value from the piecewise function
        let y = this.trigInterpolate(this.t, this.T, this.H)
        // the interval is multiplied by the x interval shift
        // see what happens with this commented out code
        //let x = this.trigInterpolate(this.t + this.T/4, this.T, this.H)
        let x = this.linearinterpolate(this.t +this.T*this.xIntervalShift/2, this
   .T*this.xIntervalShift, this.H)
```

```
        this.drawCircle(x+this.x_b,y+this.y_b, this.r)
    }
    trigInterpolate(t,T,H){
        let y = (H/2) * Math.cos( (2*Math.PI/T) *t) + H/2
        return y
    }
}
/**
 *Group of trigonometrically moving balls
 * @param {number} x_b base x position
 * @param {number} y_b base y position
 * @param {number} radius radius
 * @param {string} fillColour fill colour
 * @param {number} T total Tick interval (50 ticks = about 1 second)
 * @param {number} H total Height covered by up/down motion
 */
class TrigBallGroup extends QuadraticBallGroup{
    getObject(x_b,y_b,radius, randColour, randT, H, xIS){
        return new TrigBall(x_b,y_b,radius, randColour, randT, H, xIS)
    }
}
```

Listing 22: Quadratic Ball Class



14 Event Handling

We want to able to monitor **events**. If you are researching this you are looking for 'DOM events javascript'.
The main events we are concerned with are **mouse events**.
These are when when the user clicks the mouse, presses the mouse down, moves the mouse.
There are also 'touch' events, but this adds another layer of complexity and testing, so this has been avoided for this course.
There are many other events as well (you can research).

We get these events by creating a **listener** that we attach to the canvas page element (node).
The listener then calls the function that is attached to it.
When the listener 'fires' it creates an event object , which contains a substantial amount of data.
To see it, put a console.log(e) in one of the mouse functions.
We mainly want to know:

- Is the mouse down?
- Is the mouse up?
- What is the current (x,y) position of the mouse (in terms of the default canvas coordinates)?

This creates a significant block of code, so it is best to create a single object to manage this, and we can then , via inheritance, integrate it into any object that needs it.

```
/**
 * Captures mouse events
 * Note that are no parameters for the constructor
 * There is no update function - events are independent of the animation frame
 */
class InteractiveObject{
    constructor(){
        // this listen for a mouse event - anywhere on the canvas
        canvas.addEventListener('mousedown', this.mDown.bind(this));
        canvas.addEventListener('mouseup', this.mUp.bind(this));
        canvas.addEventListener('mousemove', this.mMove.bind(this));
        canvas.addEventListener('mouseleave', this.mLeave.bind(this));
        // variables to hold where the mouse was first clicked down
        // we will need them later
        this.xStart = 0
        this.yStart = 0
        // variables to hold the current mouse position
        this.xMouse = 0;
        this.yMouse = 0;
        // it will also be helpful to know if the mouse is down
        this.mouseIsDown = false;
```

```
    }
    mDown(e){
        // update positions so this can be used in another object
        this.xStart = e.offsetX;
        this.yStart = e.offsetY;
        // yes the mouse is down
        this.mouseIsDown = true;
        //once you have got the idea, comment out these (and remove later)
        let output = "This mouse went DOWN at  x = " + e.offsetX + " and y = " + e.offsetY;
        console.log(output)
    }
    mUp(e){
        // if the mouse is up, it can't be down :)
        this.mouseIsDown = false;
        //once you have got the idea, comment out these (and remove later)
        let output = "This mouse went UP at x = " + e.offsetX + " and y = " + e.offsetY;
        console.log(output);

    }
    mMove(e){
        // update positions so this can be used in another object
        this.xMouse = e.offsetX;
        this.yMouse = e.offsetY;
        console.log("moving")
    }
    mLeave(e){
        // this might be a useful safety feature
        // we could set mouseIsDown to false when the mouse leave the canvas
        console.log("Mouse has left the canvas")
    }
}
```

Listing 23: Interactive Object

15 Basic Draggable Point

To make use of it we can 'inherit' into an interactive ball object, which will now follow the mouse when it is down.

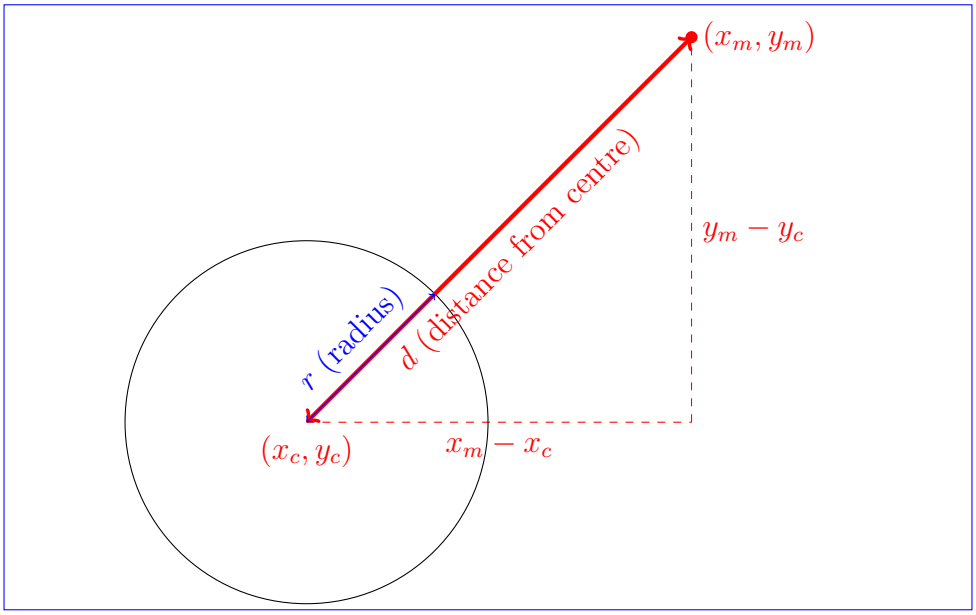
```
/**
 * Interactive Ball
 * Includes all functions from interactive object
 * @param {number} x ball centre x
 * @param {number} y ball centre y
```

```
 * @param {number} r radius of ball
 * @param {string} fill fill colour
 * @param {string} stroke stroke colour
 * @param {number} strokeWidth  width of outline
 */
class InteractiveBall extends InteractiveObject{
    // all the functions of interactive object are part of InteractiveBall
    constructor(x,y,r,fill, stroke, strokeWidth){
        // super initialises the constructor of InteractiveObject
        super()
        this.x = x;
        this.y = y;
        this.r=r;
        this.fill=fill;
        this.stroke = stroke;
        this.strokeWidth = strokeWidth;
    }
    update(){
        this.draw();
        // check if mouse is down and update x, y coordinates of the ball
        // to be the same as the x,y mouse positions
        if(this.mouseIsDown){
            this.x = this.xMouse;
            this.y = this.yMouse;
        }
    }
    draw(){
        this.drawCircle(this.x, this.y, this.r, this.fill, this.stroke, this.
   strokeWidth)
    }
    drawCircle(x,y,r,f,s,l){
        ctx.beginPath()
        ctx.arc(x, y, r, 0, 2*Math.PI)
        ctx.fillStyle = f
        ctx.strokeStyle = s
        ctx.lineWidth = l
        ctx.fill();
        ctx.stroke()
    }
}
```

Listing 24: Interactive Object

16 Better Draggable Point

We would like the ball to move only if the mouse is inside it.
This is called **hit testing**.



The distance from the centre of the circle to where the mouse is , is:

$$d = \sqrt{(x_m - x_c)^2 + (y_m - y_c)^2}$$

If $d < r$, then the mouse is inside the circle,
Otherwise it is not.

```
console.log("point js file has been called");
class Point{
// class Point x,y,r, stroke, fill, over, canvas
constructor(x,y,r, stroke, fill, over){
    //basic position, size and colours
    this.x = x;
    this.y = y;
    this.r = r;
    this.stroke = stroke;
    this.fill = fill;
    this.over = over;
    //set true if mouse inside point circle
    this.inBounds = false;
    //cointinually registered mouse position
    this.xMouse = 0;
    this.yMouse = 0;
    //listeners
    canvas.addEventListener('mousedown', this.mDown.bind(this));
```

```
19      canvas.addEventListener('mousemove', this.mMove.bind(this));
20      canvas.addEventListener('mouseup', this.mUp.bind(this));
21  }
22  mDown(e){
23      // if the mouse is pressed (goes down) and the mouse is inside the point
        circle,
24      // set the this object as taken
25      if(this.inBounds){
26          Point.taken = this;
27      }
28  }
29  mMove(e){
30      // event registered every time the mouse moves
31      // object variables updated with current mouse position
32      this.xMouse = e.offsetX;
33      this.yMouse = e.offsetY;
34      //update boundary boolean
35      this.inBounds = this.boundsCheck(this.xMouse, this.yMouse, this.x, this.y,
        this.r);
36  }
37  mUp(e){
38      //when mouse goes up set taken point as nothing
39      //hence deselect this point
40      Point.taken = "";
41  }
42  /**
43   * called from animation loop
44   */
45  update(){
46  // make x,y coordinates of the point the same as the mouse position
47  // if the point has been taken
48      if(Point.taken == this){
49          this.x=this.xMouse;
50          this.y=this.yMouse;
51      }
52      this.draw();
53  }
54  draw(){
55      // change fill state if mouse is over or the point is selected
56      if(this.inBounds || Point.taken == this){
57      ctx.fillStyle= this.over;
58      }else{
59          ctx.fillStyle= this.fill;
60      }
61      ctx.strokeStyle = this.stroke;
62      ctx.lineWidth = 2;
63      ctx.beginPath()
```

```
64      ctx.arc(this.x,this.y, this.r, 0, 2*Math.PI);
65      ctx.fill();
66      ctx.stroke();
67  }
68  /**
69   * Pythagoras distance check
70   * @param  x,y,positions of mouse and of point circle and radius of point circle
        (number)
71   * @return boolean
72   */
73  boundsCheck(x_1, y_1, x_2, y_2, r){
74          var d = Math.sqrt( Math.pow(x_2 - x_1, 2) + Math.pow(y_2 - y_1, 2) );
75          if(d<r){
76              return true;
77          }else{
78              return false;
79          }
80  }
81  /**
82   * Make x, y coordinates of point available outside of object
83   * @return number
84   */
85  getX(){
86      return this.x;
87  }
88  getY(){
89      return this.y;
90  }
91  }
92  // static variable available to all Point objects
93  // the same for all Point objects
94  // means only one Point can be selected and moveable
95  Point.taken="";
```

Listing 25: Python example

17 Buttons