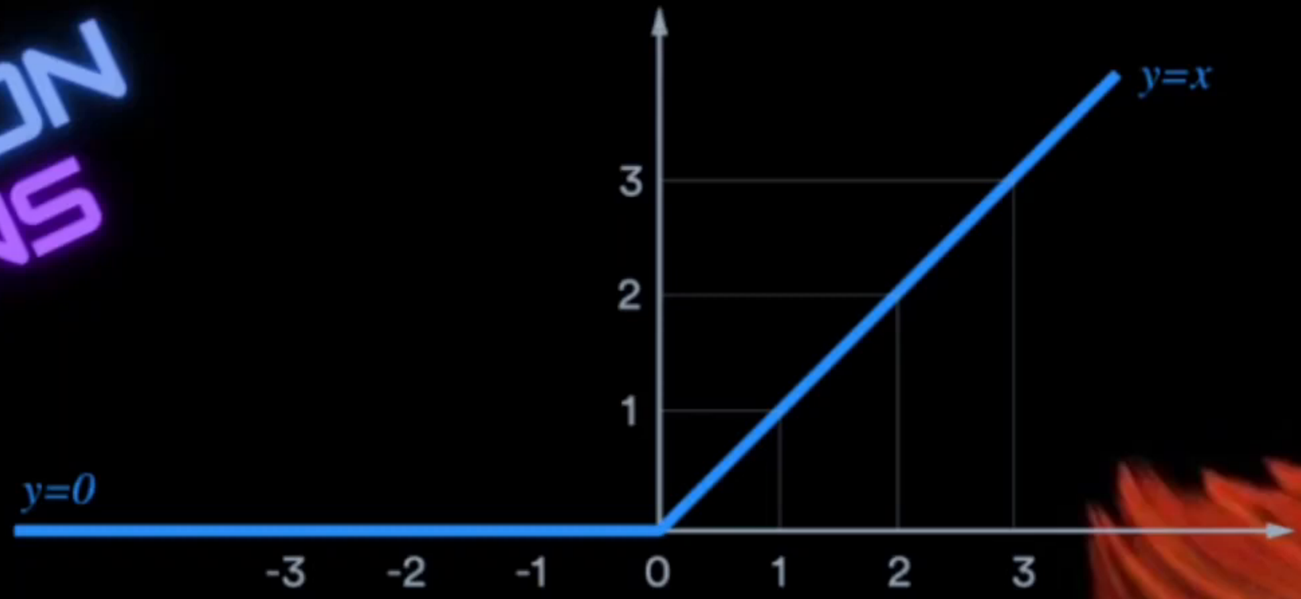
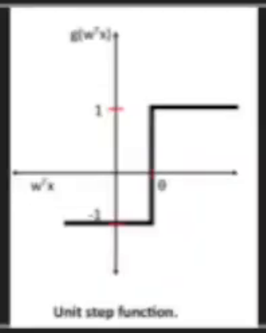
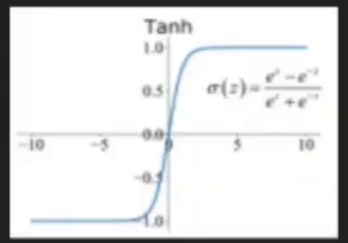
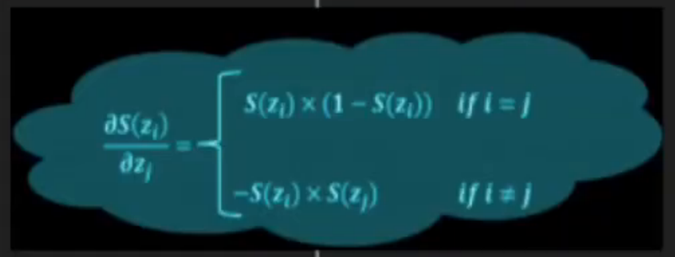
ACTIVATION FUNCTIONS



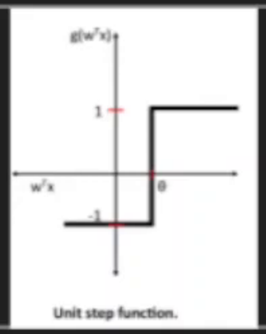
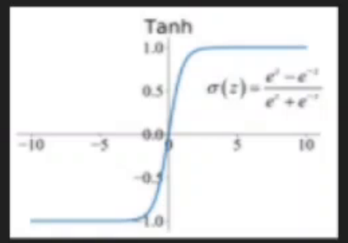
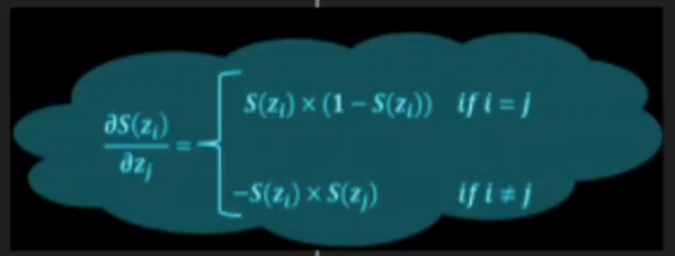

# RELU ACTIVATION


Programming

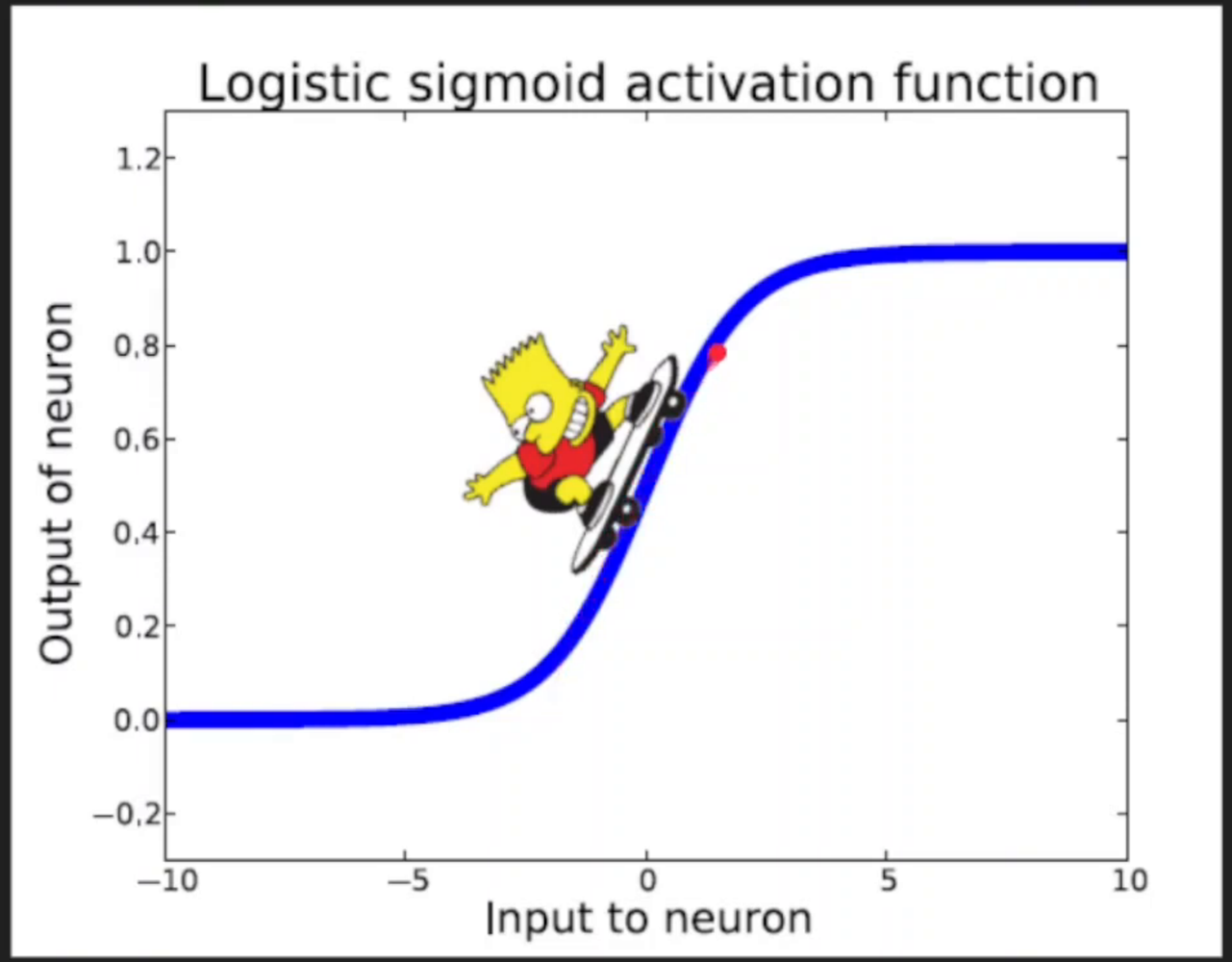
# Recap

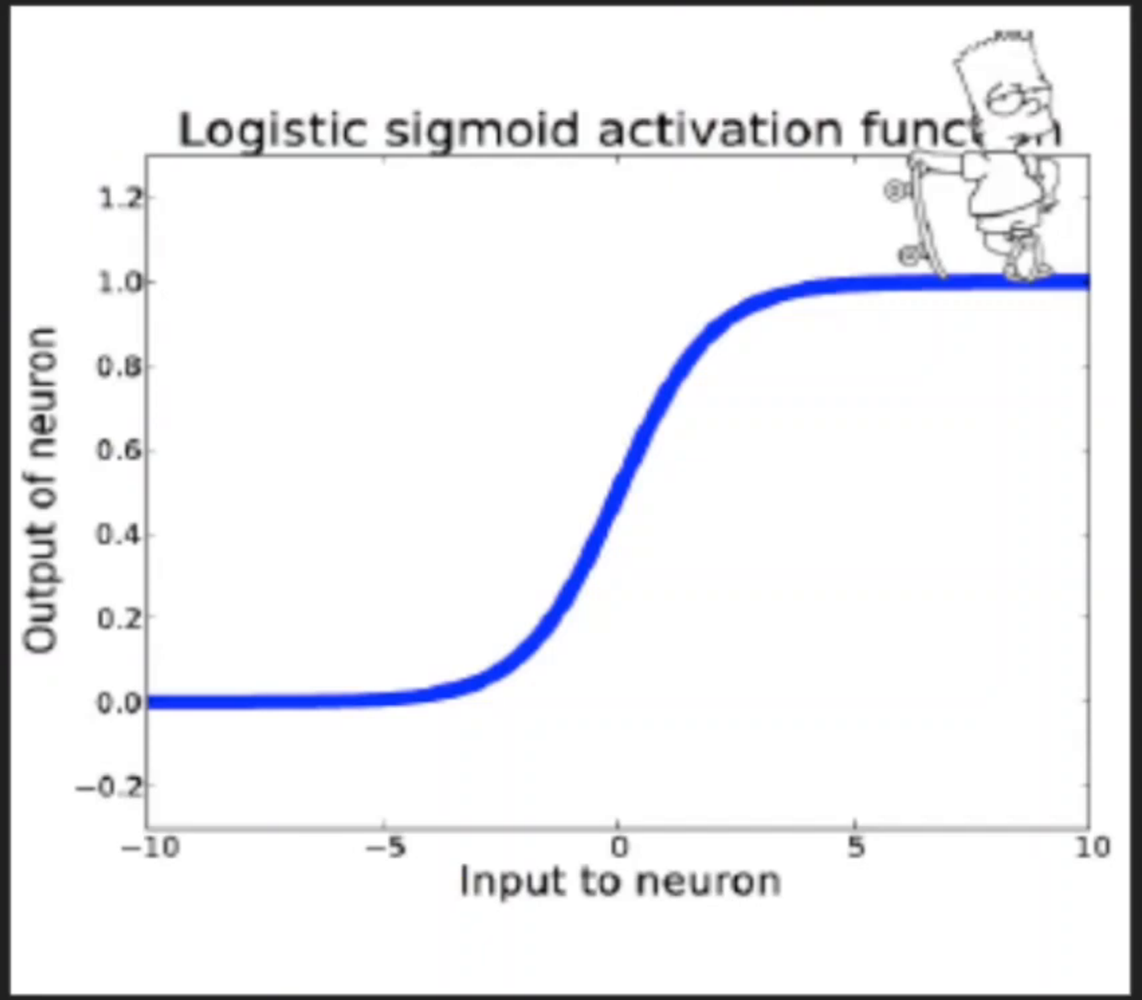
| | | | | |
|---|---|---|---|---|
| **Step** | Binary step<br>$f(x) = \begin{cases} 0 & for\ x < 0 \\ 1 & for\ x \geqslant 0 \end{cases}$ | **f'(x)=0** |  | ***Not used much**<br>***Binary** |
| **Sigmoid** | $S(x) = \frac{1}{1+e^{-x}}$ | **f'(x) = f(x)* (1-f(x))** |  | *** Binary**<br>*** Preferred** |
| **Tanh** | Tanh Function<br>$a = \frac{e^{z} - e^{-z}}{e^{z} + e^{-z}}$ | **f'(x) = 1- f(x)^2** |  | *** Binary**<br>*** Better than Sigmoid**<br>*** Hidden layers** |
| **Softmax** | $\sigma(\vec{z})_i = \frac{e^{z_i}}{\sum_{j=1}^{K} e^{z_j}}$ |  | *** Multi-class**<br>*** Output layers** |

# Recap

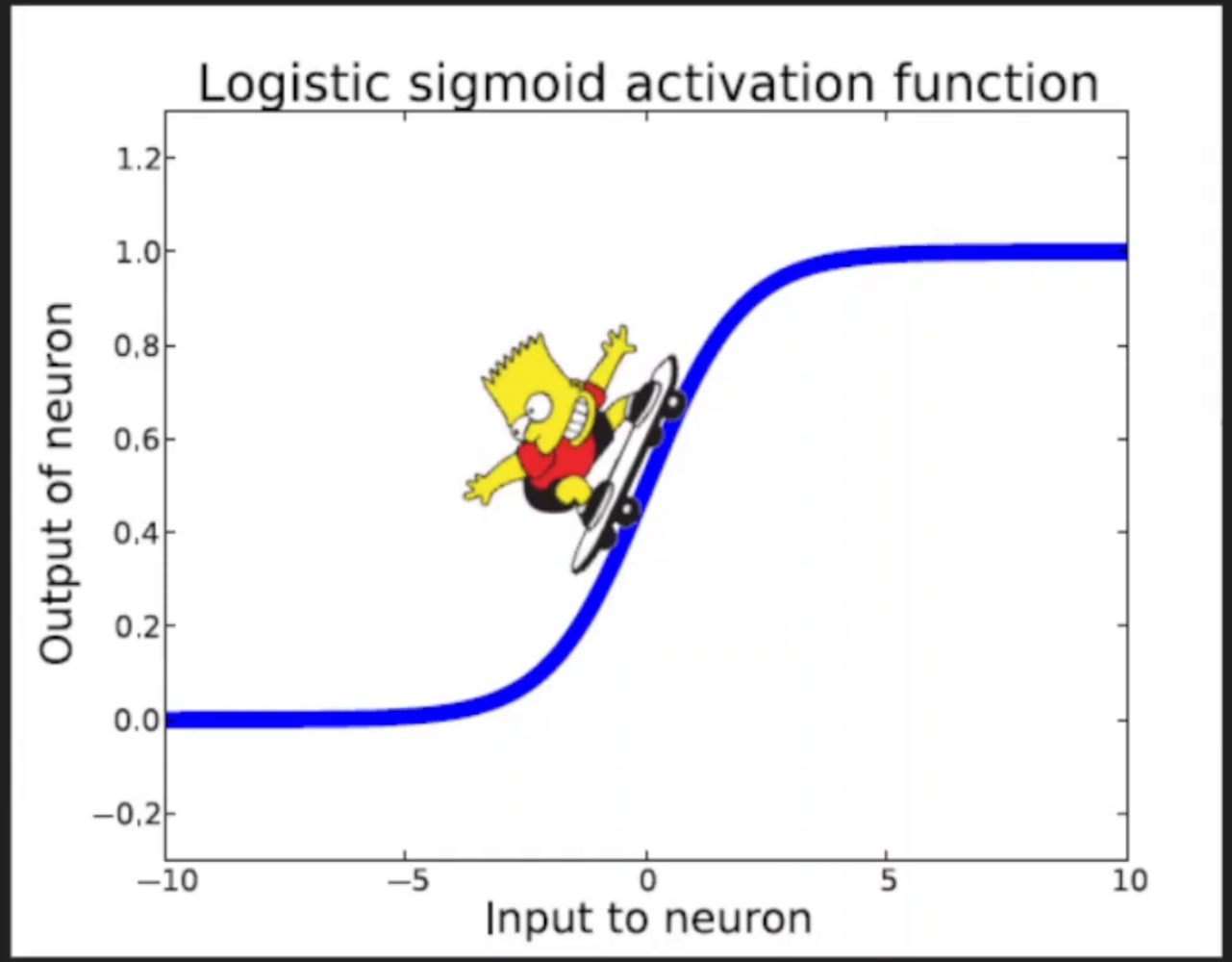
| | | | | |
|---|---|---|---|---|
| **Step** | Binary step<br>$f(x) = \begin{cases} 0 & for\ x < 0 \\ 1 & for\ x \geqslant 0 \end{cases}$ | **f'(x)=0** |  | ***Not used much**<br>***Binary** |
| **Sigmoid** | $S(x) = \frac{1}{1+e^{-x}}$ | **f'(x) = f(x)* (1-f(x))** |  | *** Binary**<br>*** Preferred** |
| **Tanh** | Tanh Function<br>$a = \frac{e^{z} - e^{-z}}{e^{z} + e^{-z}}$ | **f'(x) = 1-f(x)^2** |  | *** Binary**<br>*** Better than Sigmoid**<br>*** Hidden layers** |
| **Softmax** | $\sigma(\vec{z})_i = \frac{e^{z_i}}{\sum_{j=1}^{K} e^{z_j}}$ |  | *** Multi-class**<br>*** Output layers** |

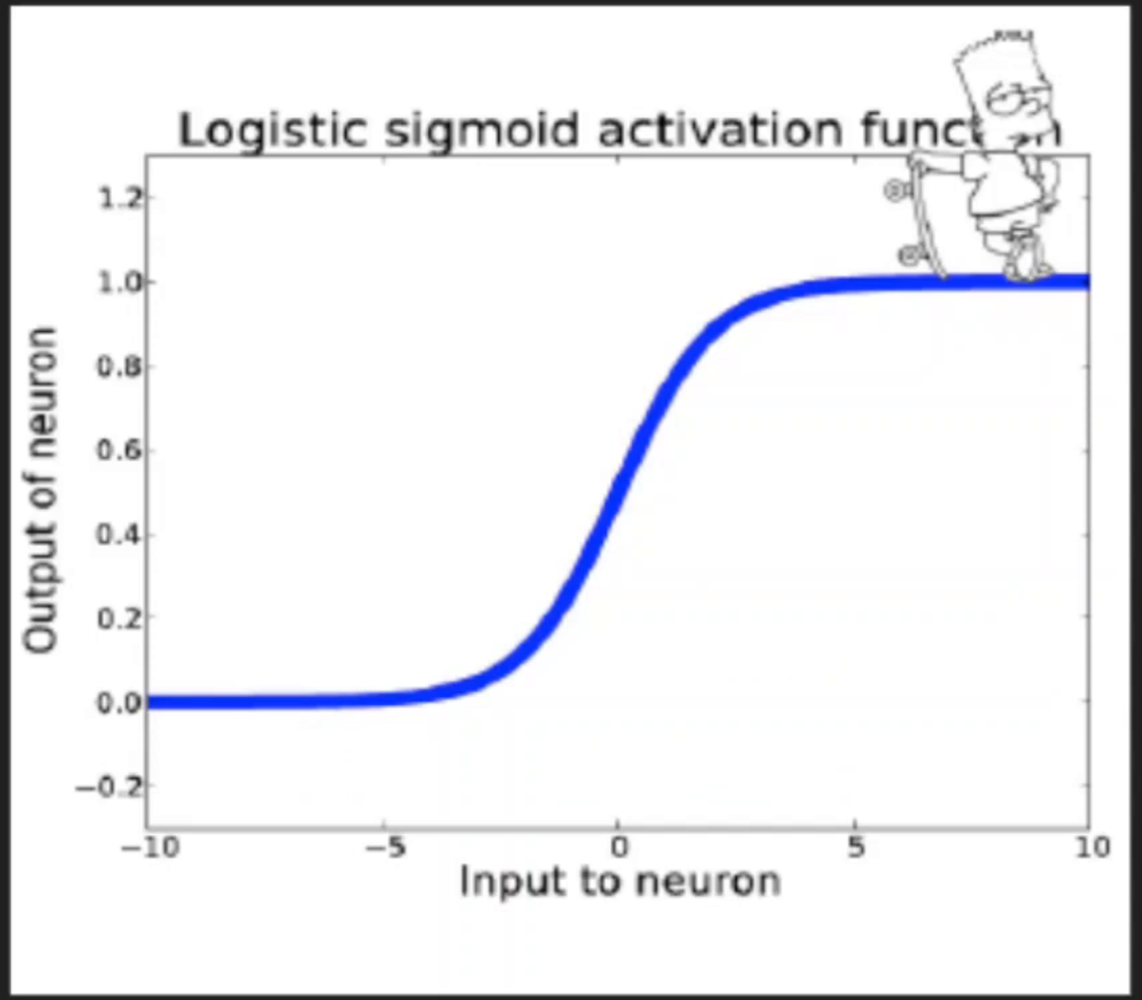
# Vanishing Gradient



# Vanishing Gradient



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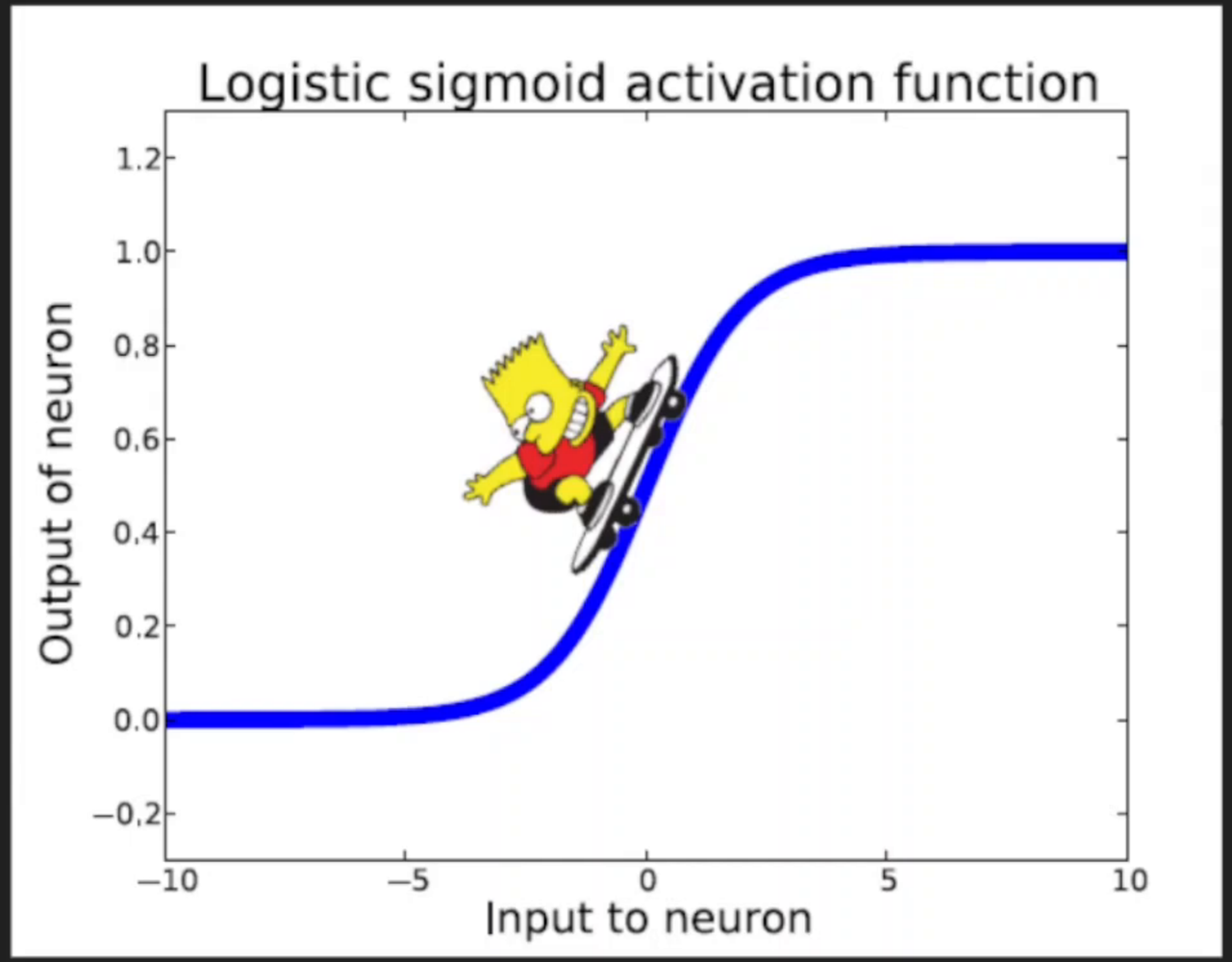
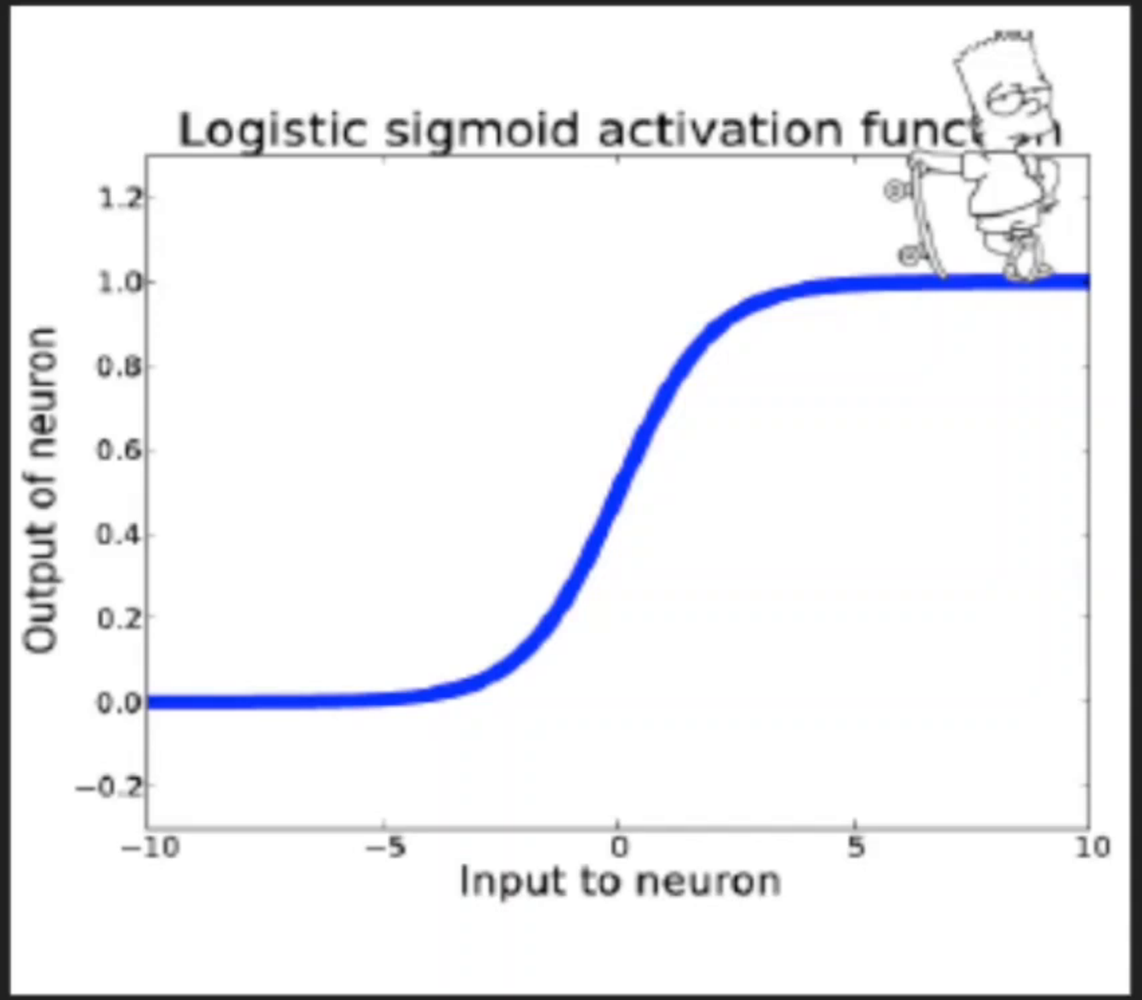
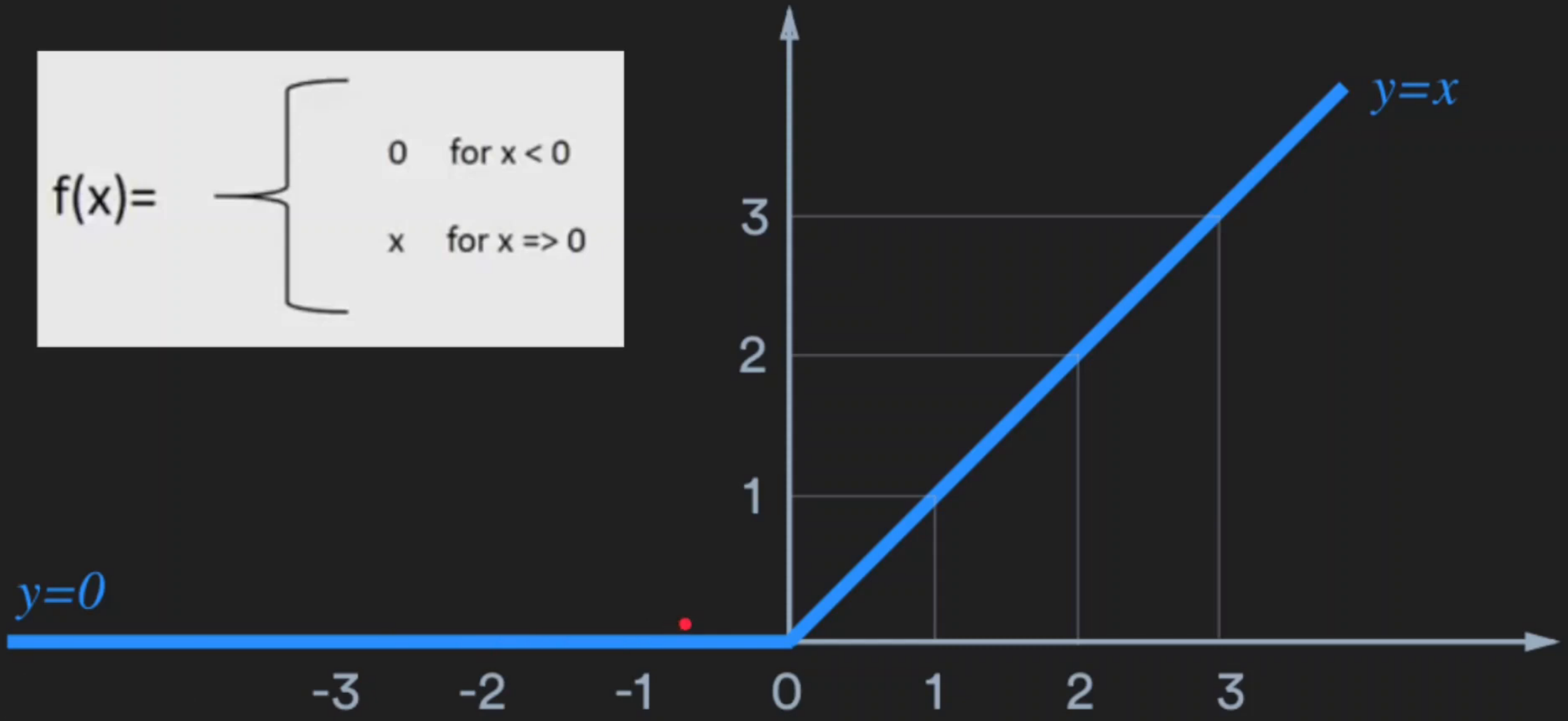


# ReLU

$$f(x)=\begin{cases} 0 & \text{for } x < 0 \\ x & \text{for } x \Rightarrow 0 \end{cases}$$



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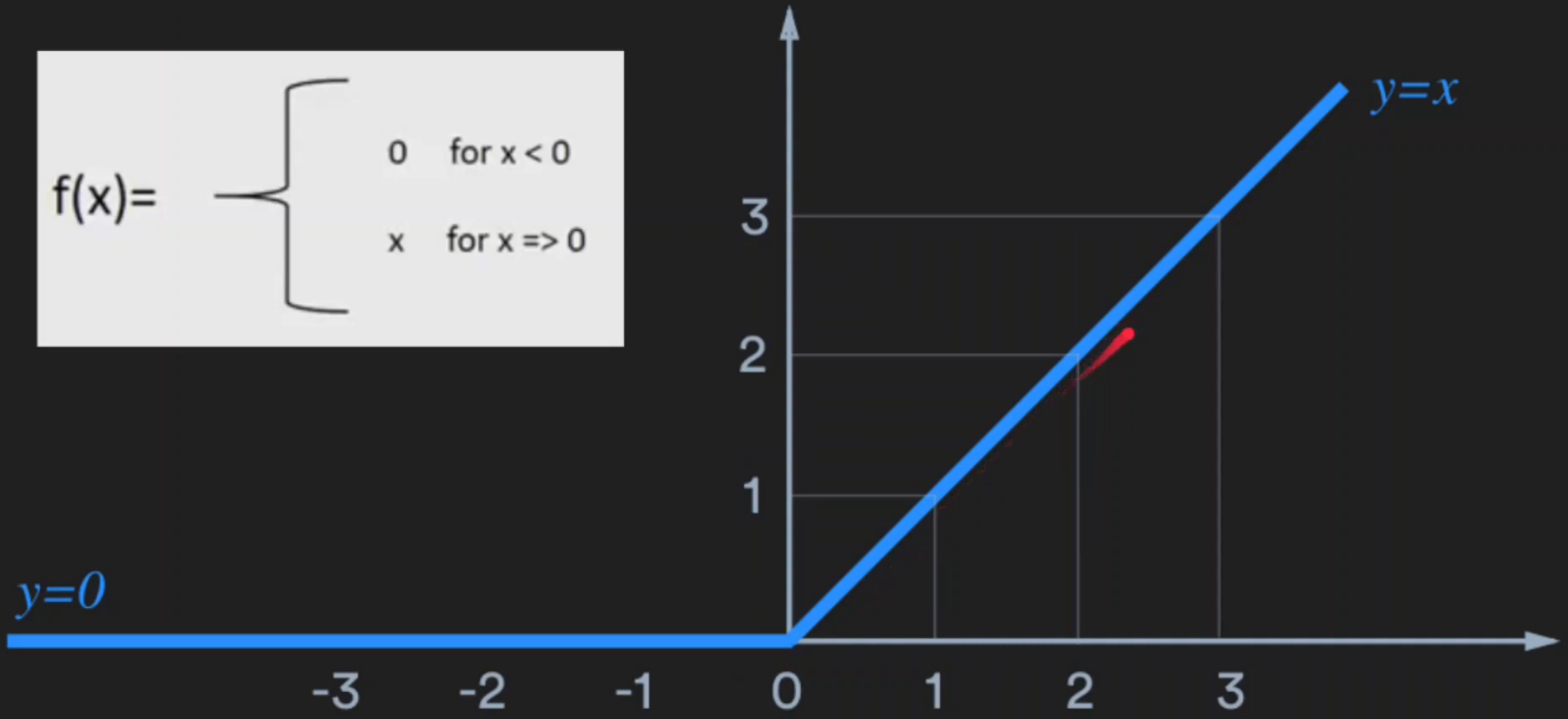

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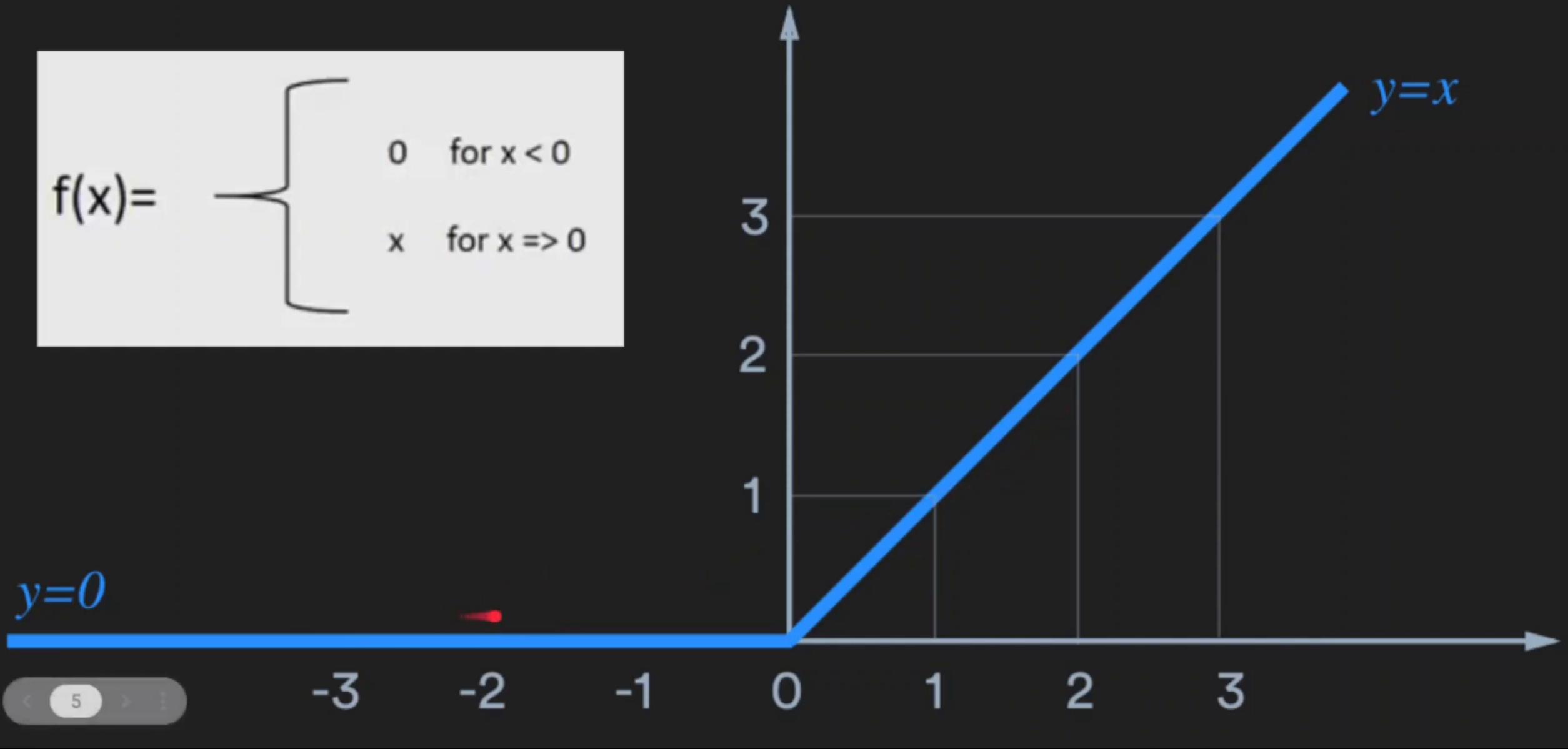

# ReLU Layer

**Filter 1 Feature Map**

| | | | |
|---|---|---|---|
| 9 | 3 | 5 | -8 |
| -6 | 2 | -3 | 1 |
| 1 | 3 | 4 | 1 |
| 3 | -4 | 5 | 1 |

| | | | |
|---|---|---|---|
| 9 | 3 | 5 | 0 |
| 0 | 2 | 0 | 1 |
| 1 | 3 | 4 | 1 |
| 3 | 0 | 5 | 1 |

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**Filter 1 Feature Map**

| | | | |
|---|---|---|---|
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| | | | |
|---|---|---|---|
| 9 | 3 | 5 | 0 |
| 0 | 2 | 0 | 1 |
| 1 | 3 | 4 | 1 |
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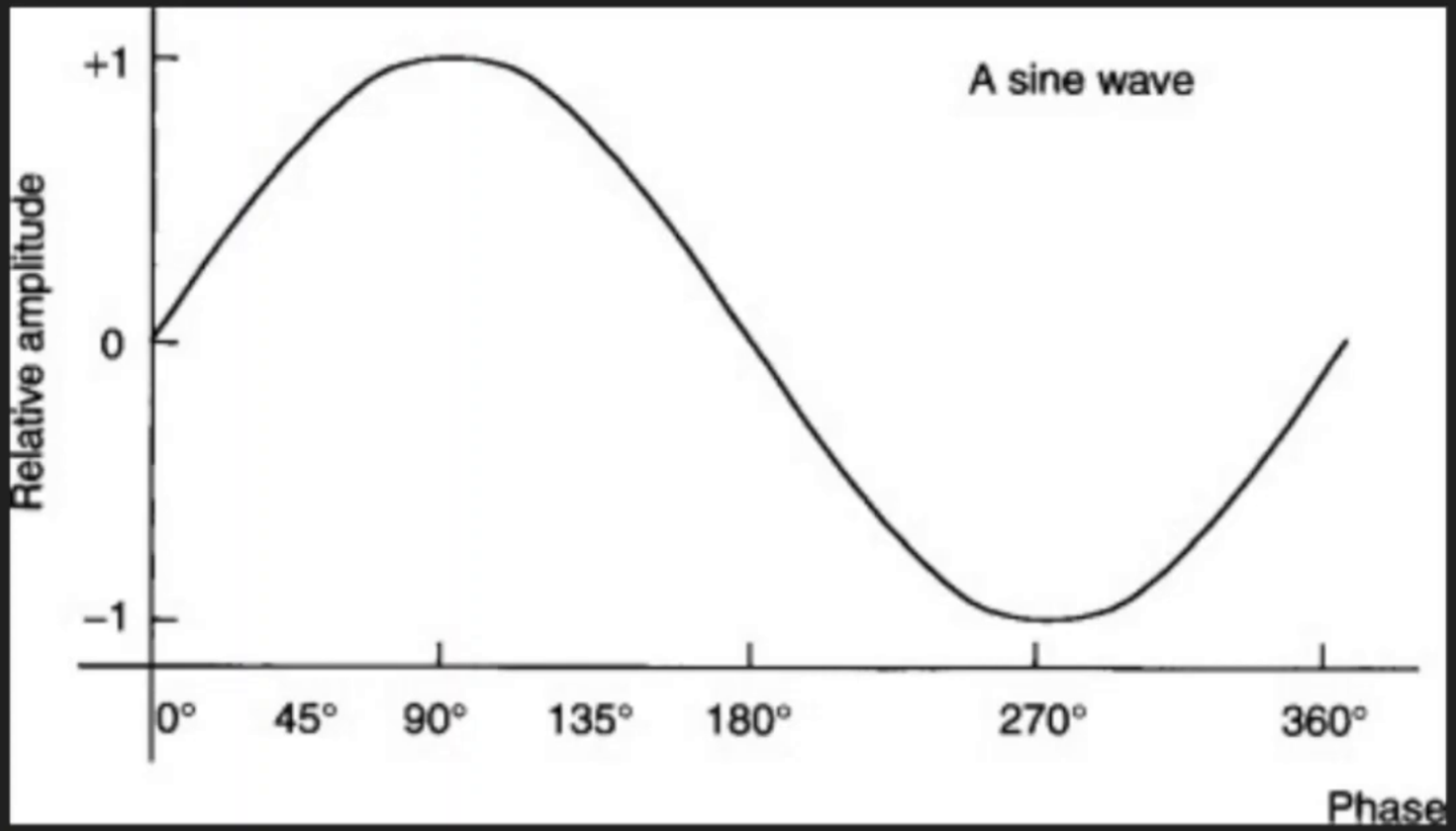
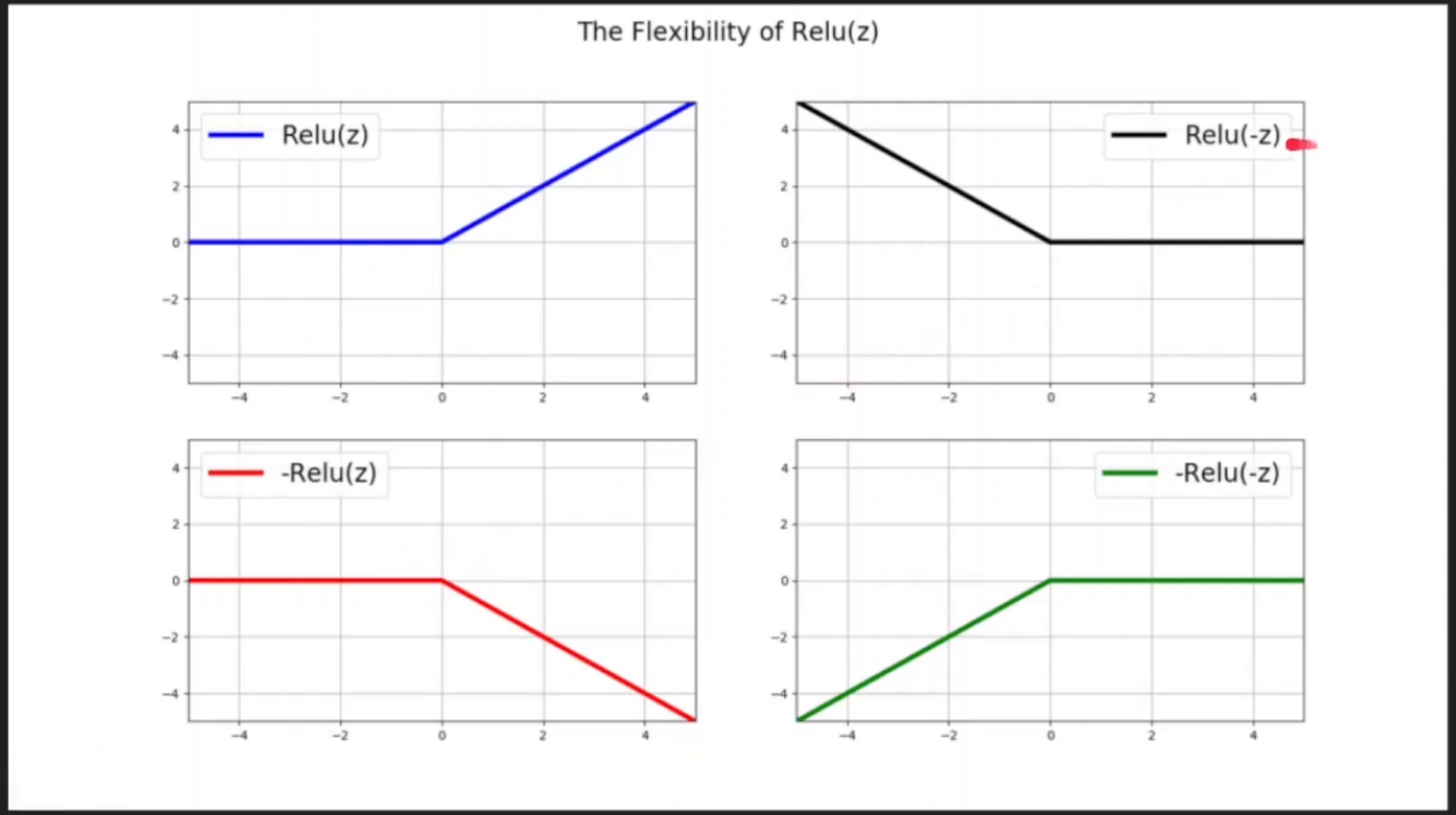
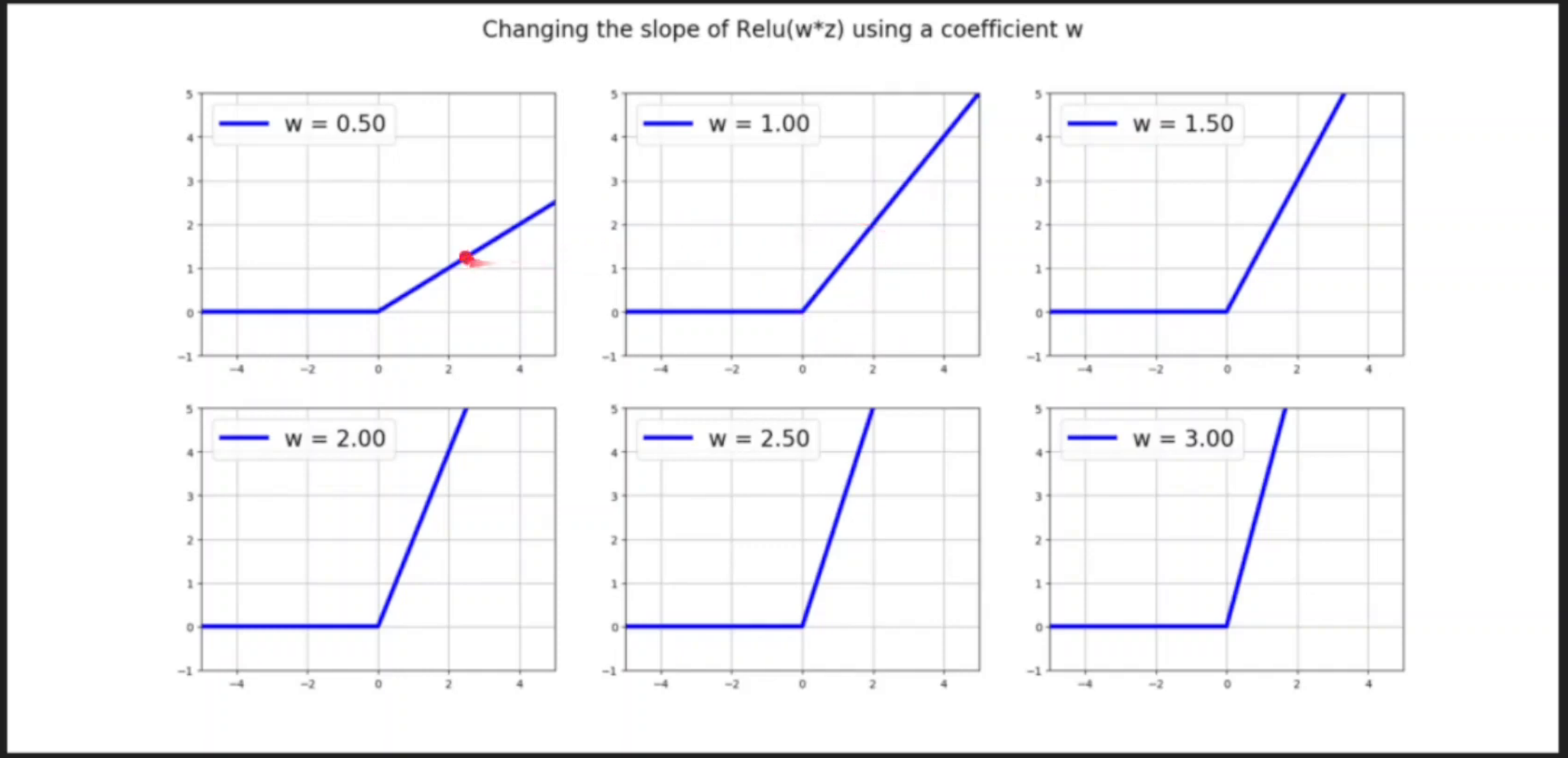
# Fit the Sine wave



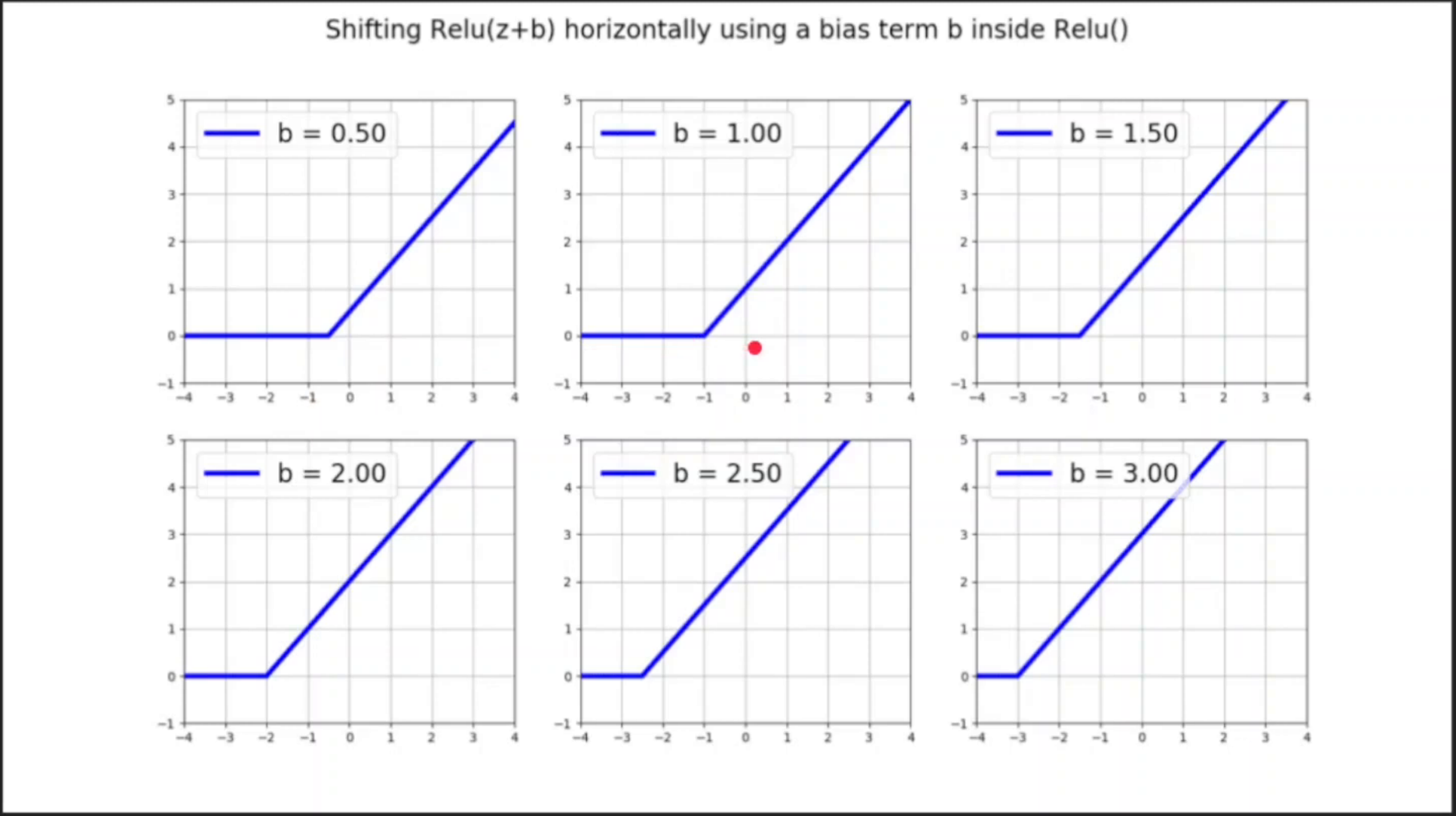
# ReLU function variations - Negative inputs



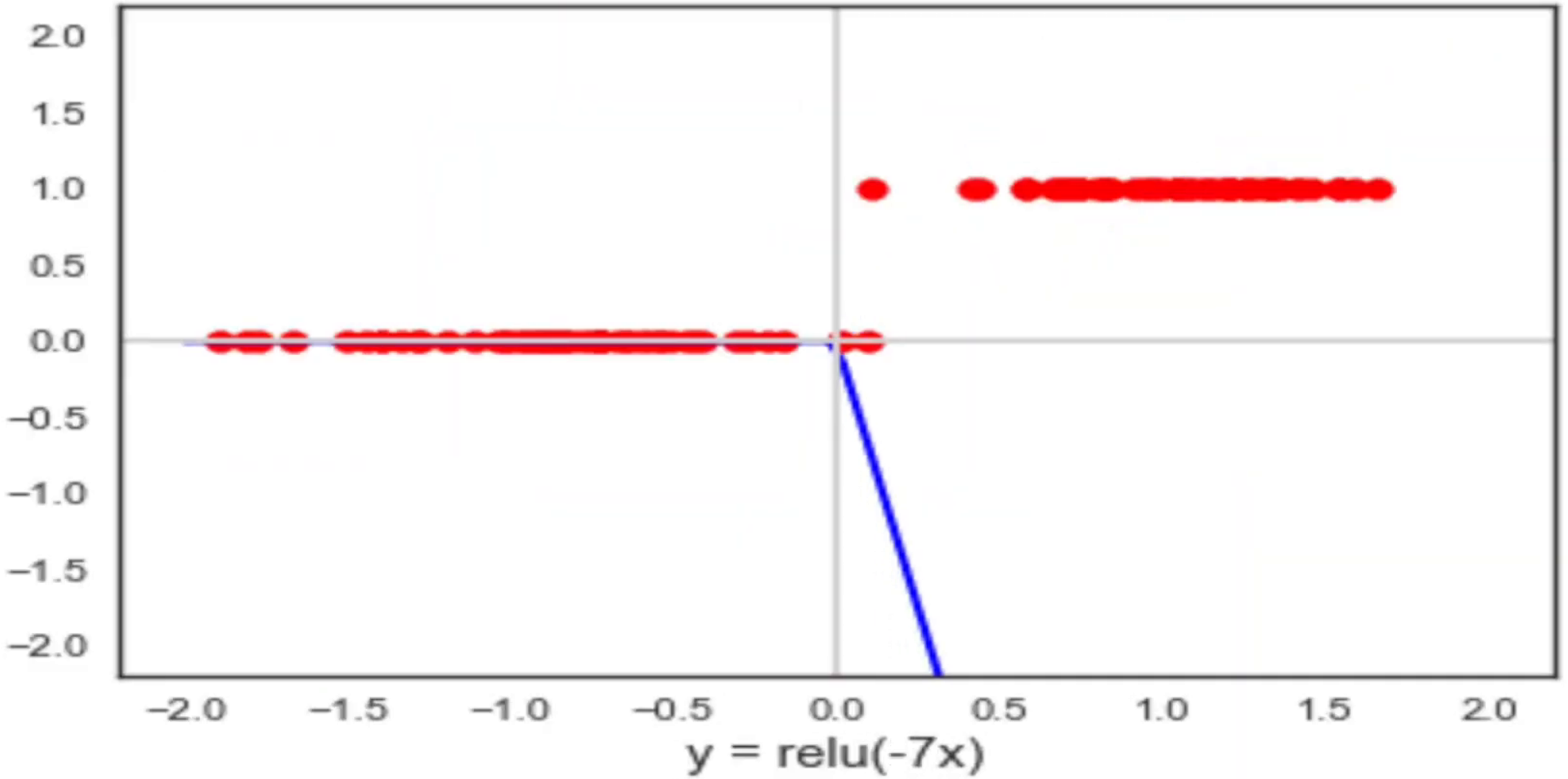
# Changing Slope



# Changing Bias - Horizontal



# ReLU in Action



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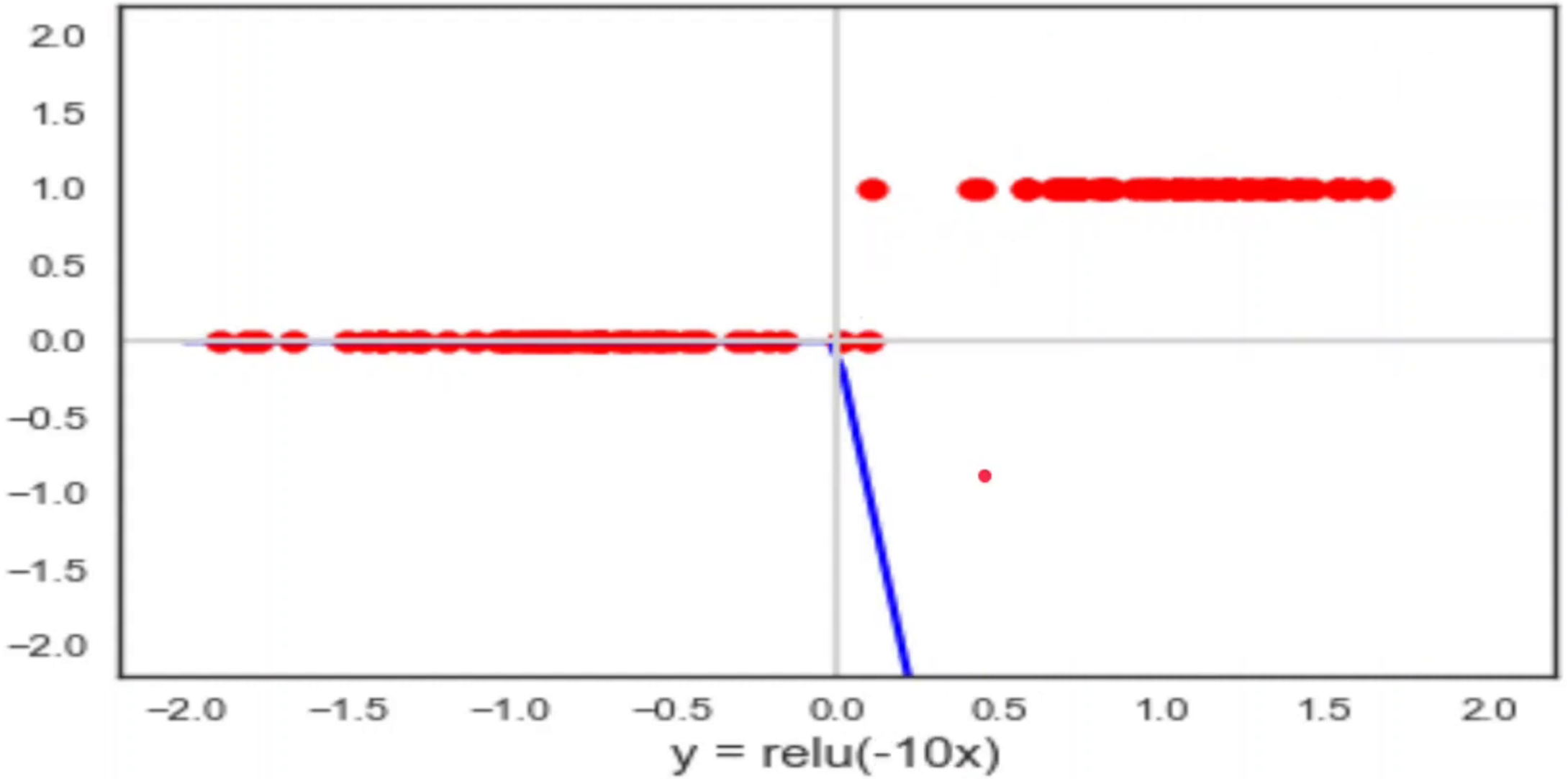
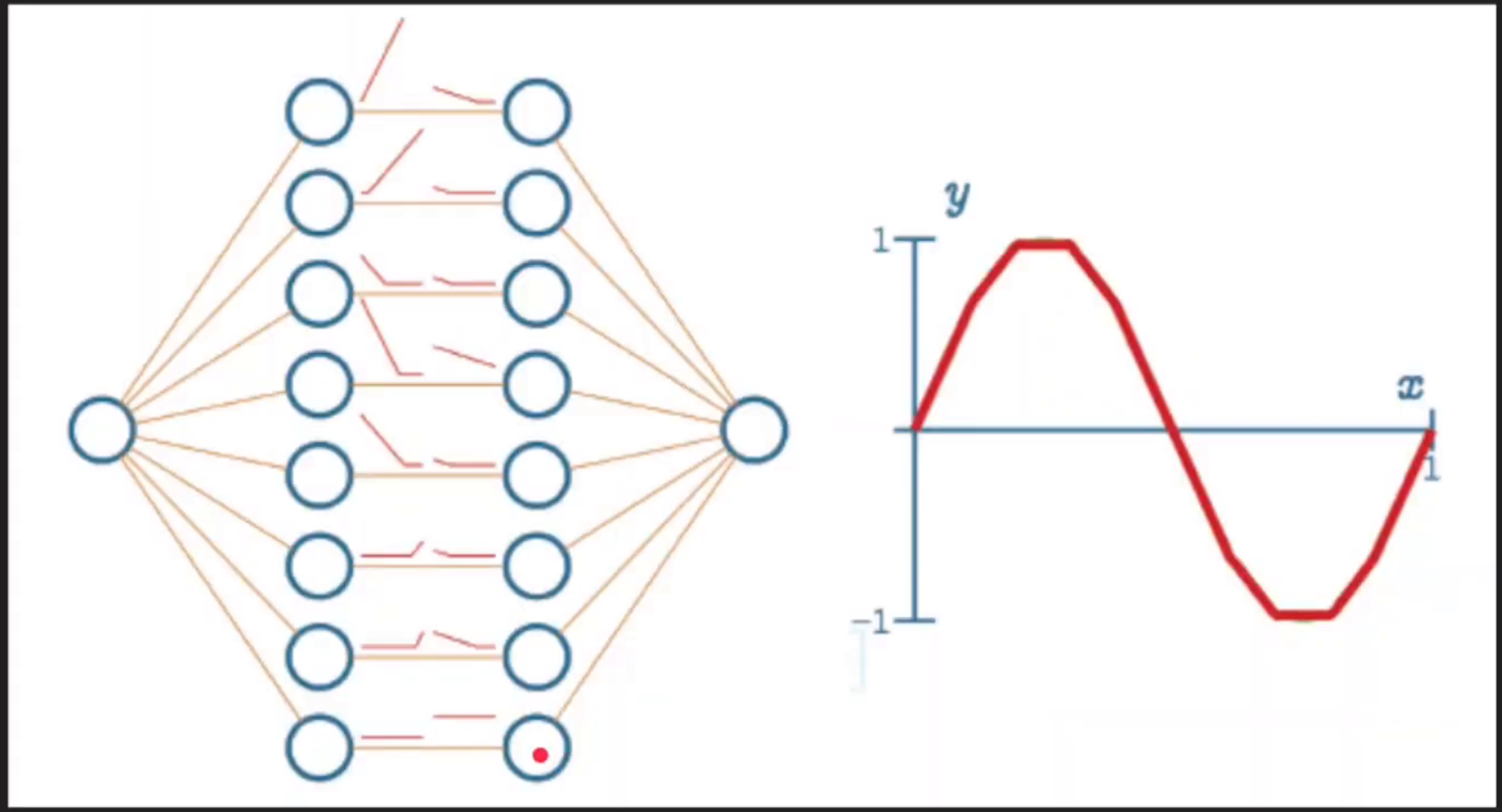
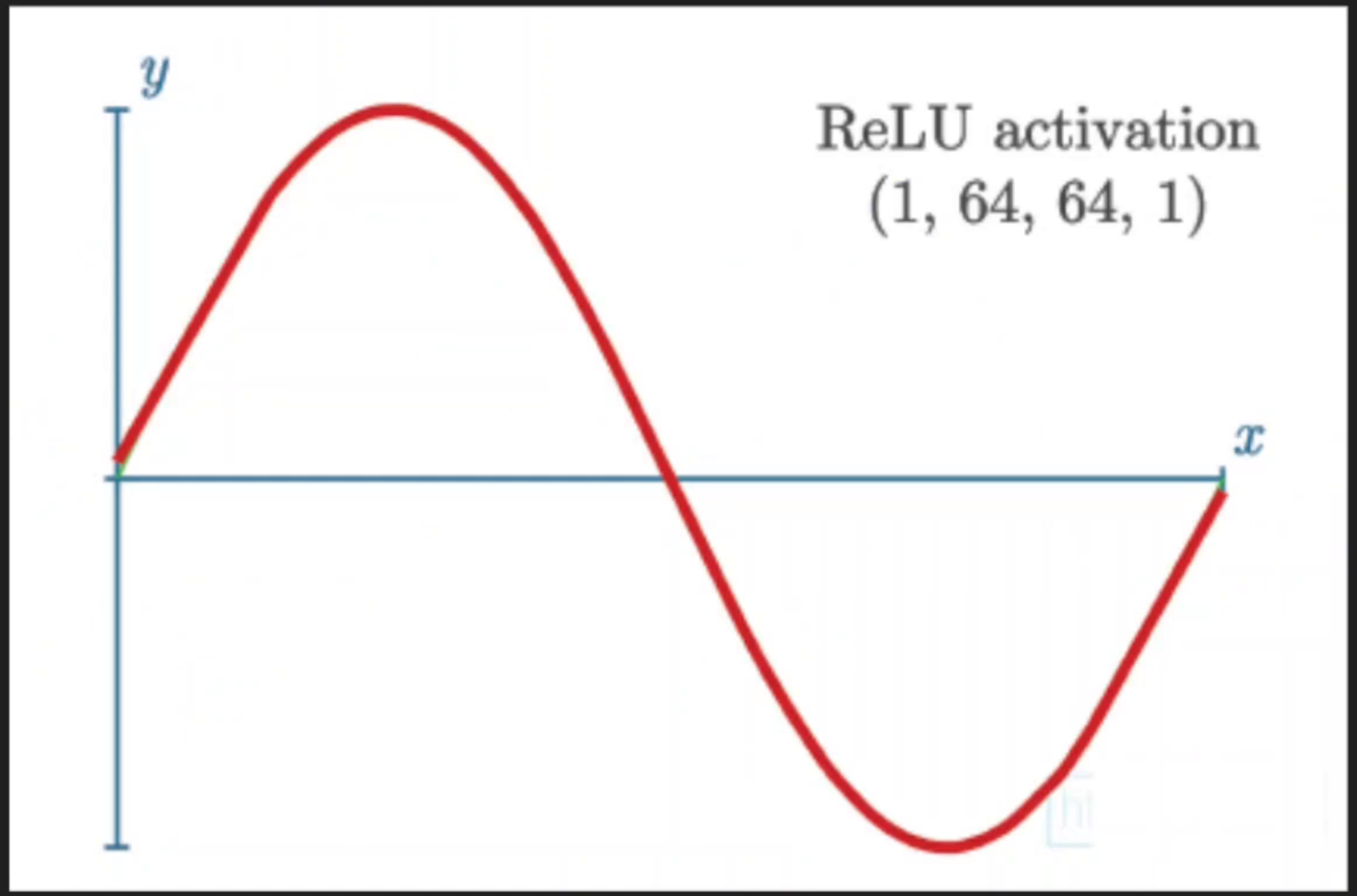


# Sine wave Approximation



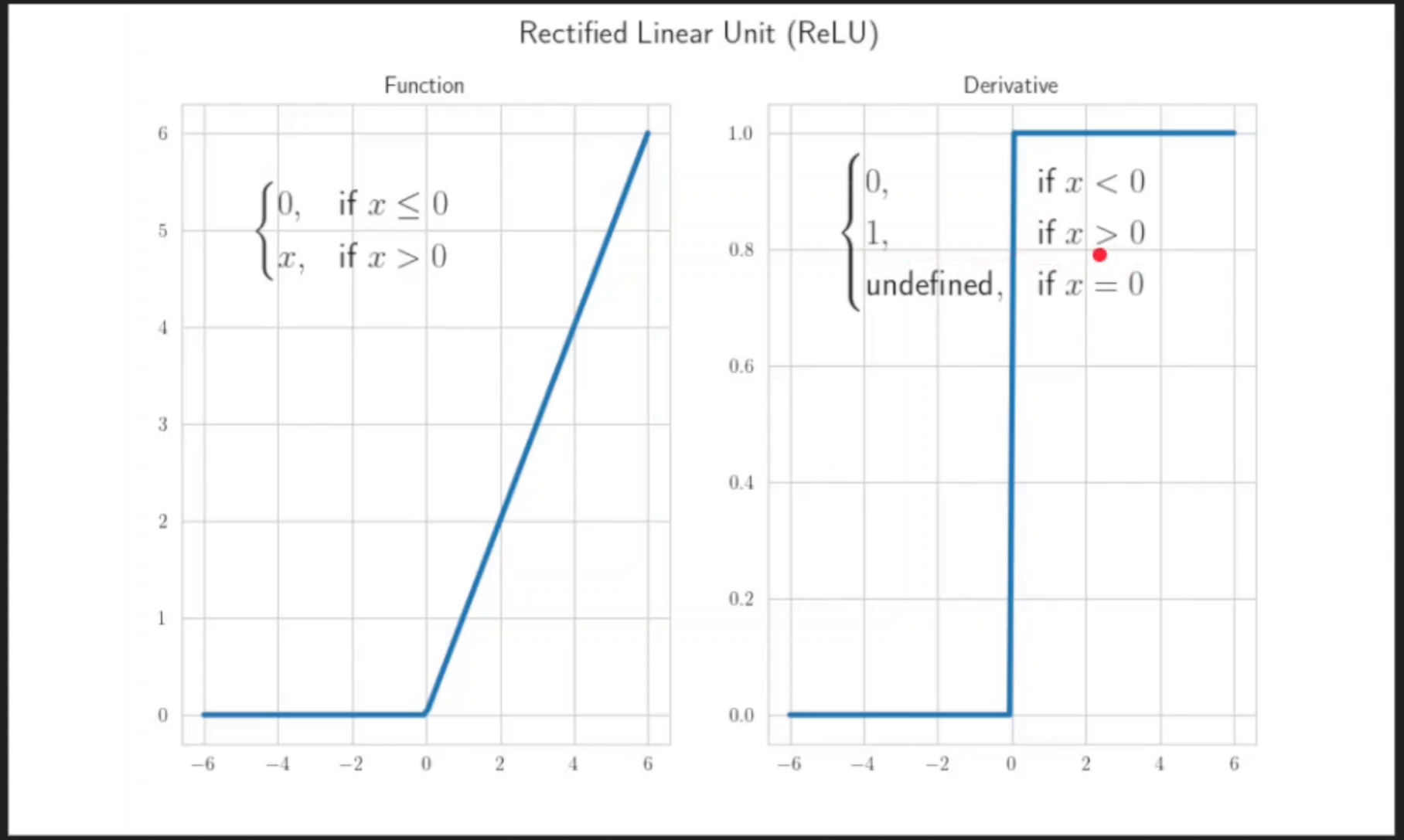

**Arch - (1,8,8,1)**

# Sine wave Approximation

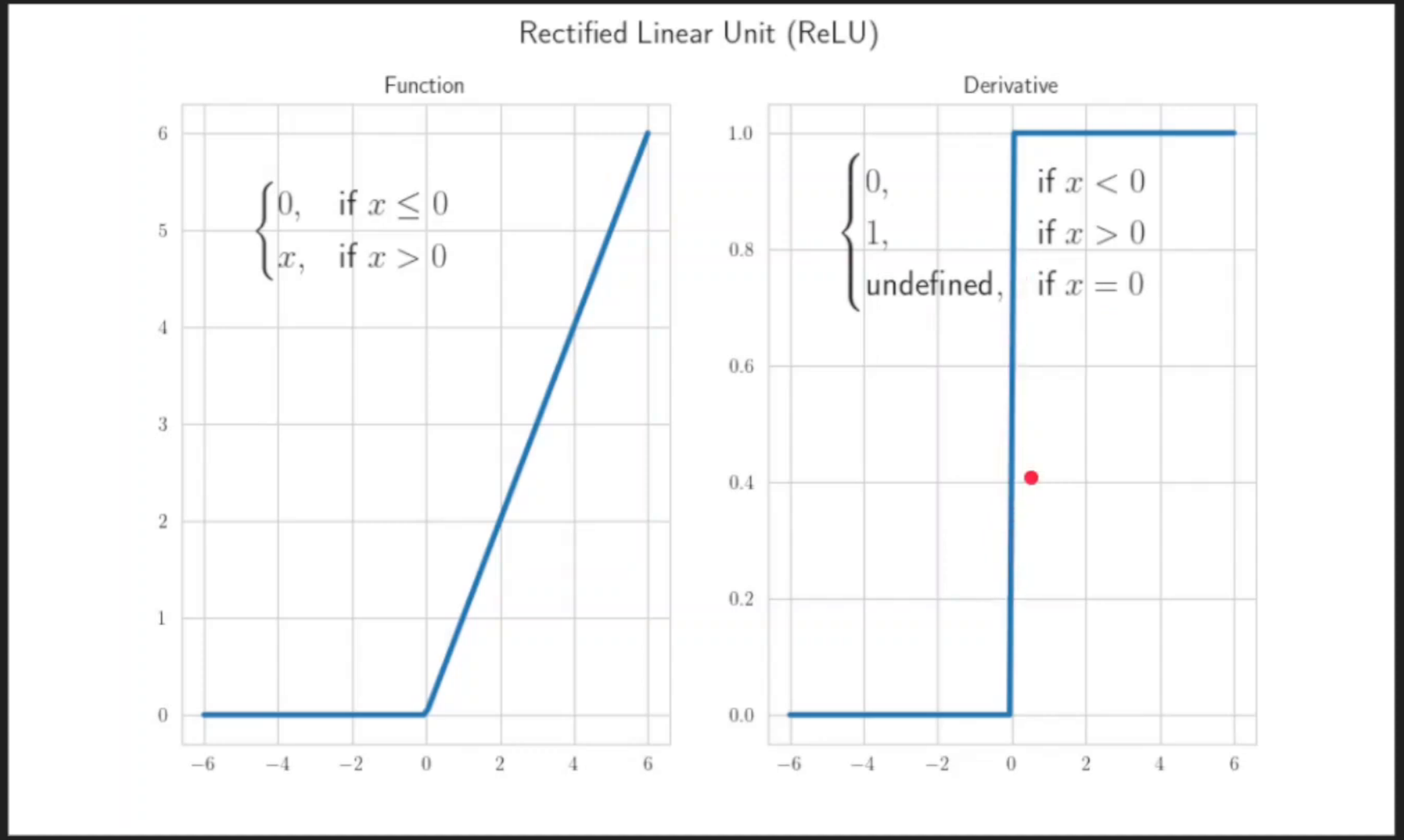



**Arch - (1,64,64,1)**

# Derivative


Rectified Linear Unit (ReLU)
Function
$\begin{cases} 0, & \text{if } x \leq 0 \\ x, & \text{if } x > 0 \end{cases}$
6
5
4
3
2
1
0
−6
−4
−2
0
2
4
6
Derivative
$\begin{cases} 0, & \text{if } x < 0 \\ 1, & \text{if } x > 0 \\ \text{undefined}, & \text{if } x = 0 \end{cases}$
1.0
0.8
0.6
0.4
0.2
0.0
−6
−4
−2
0
2
4
6

# Derivative


Rectified Linear Unit (ReLU)
Function
$\begin{cases} 0, & \text{if } x \leq 0 \\ x, & \text{if } x > 0 \end{cases}$
Derivative
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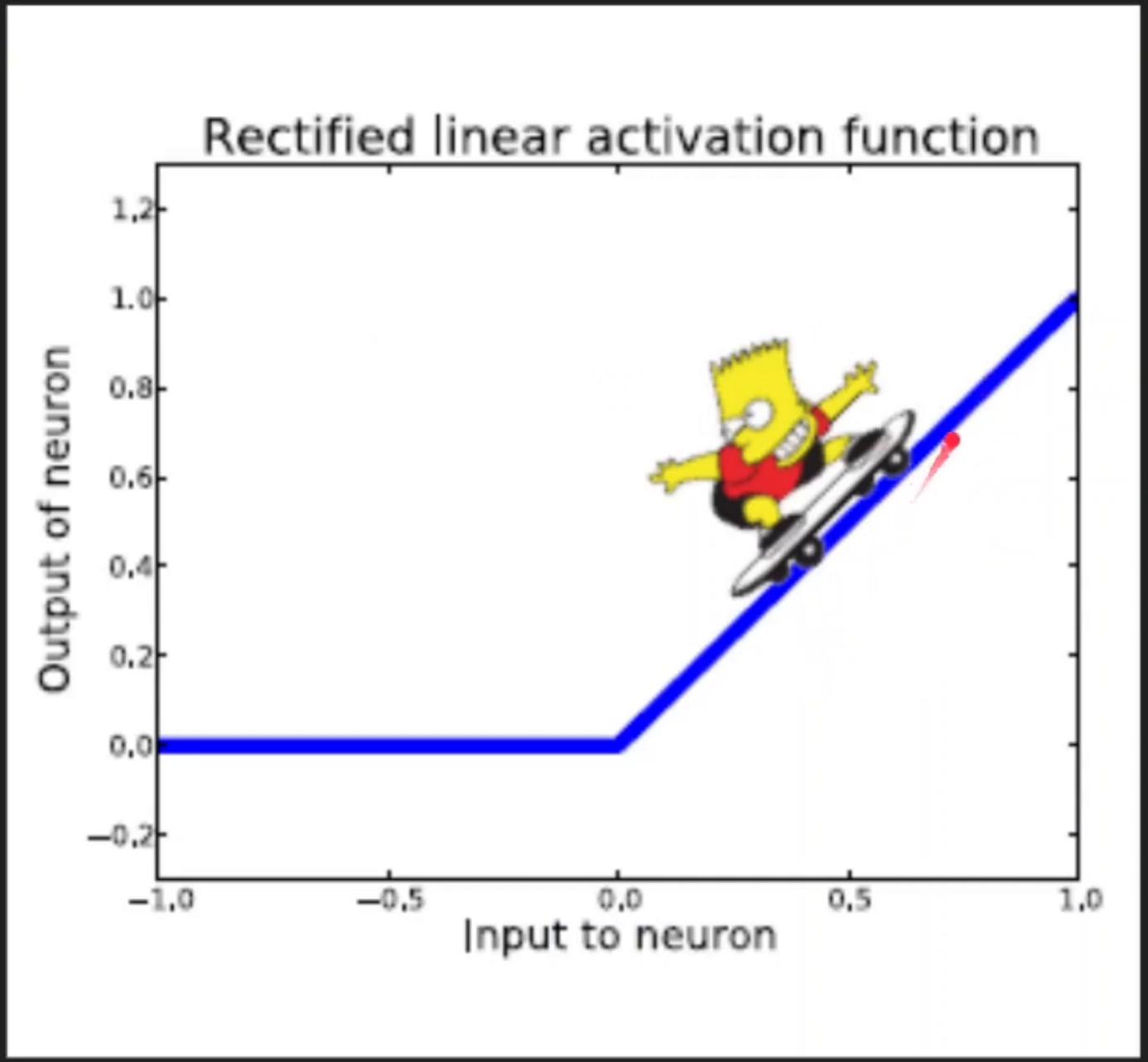
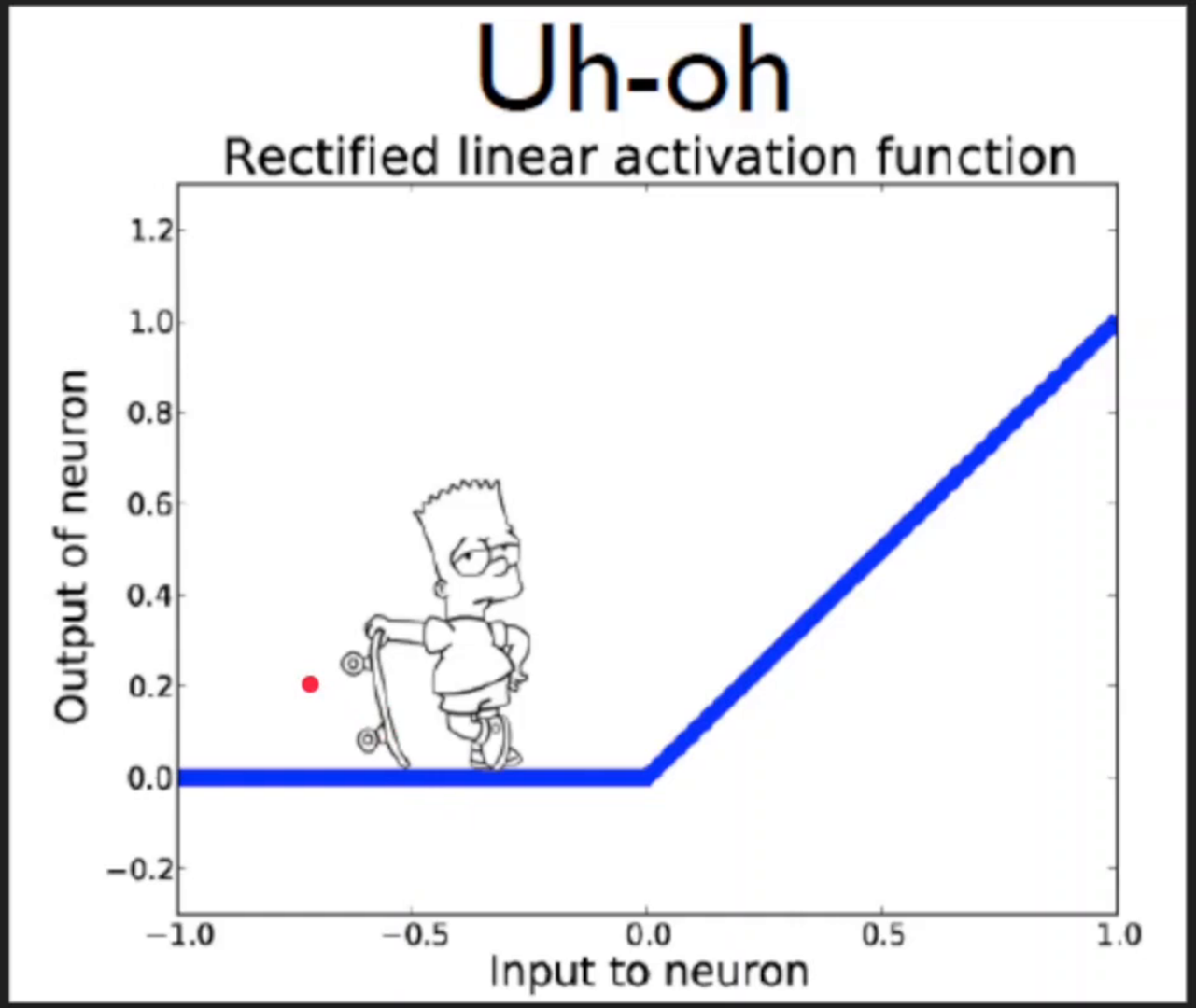

Rectified linear activation function
Output of neuron
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−1.0
−0.5
0.0
0.5
1.0
Input to neuron

# Dead Neurons



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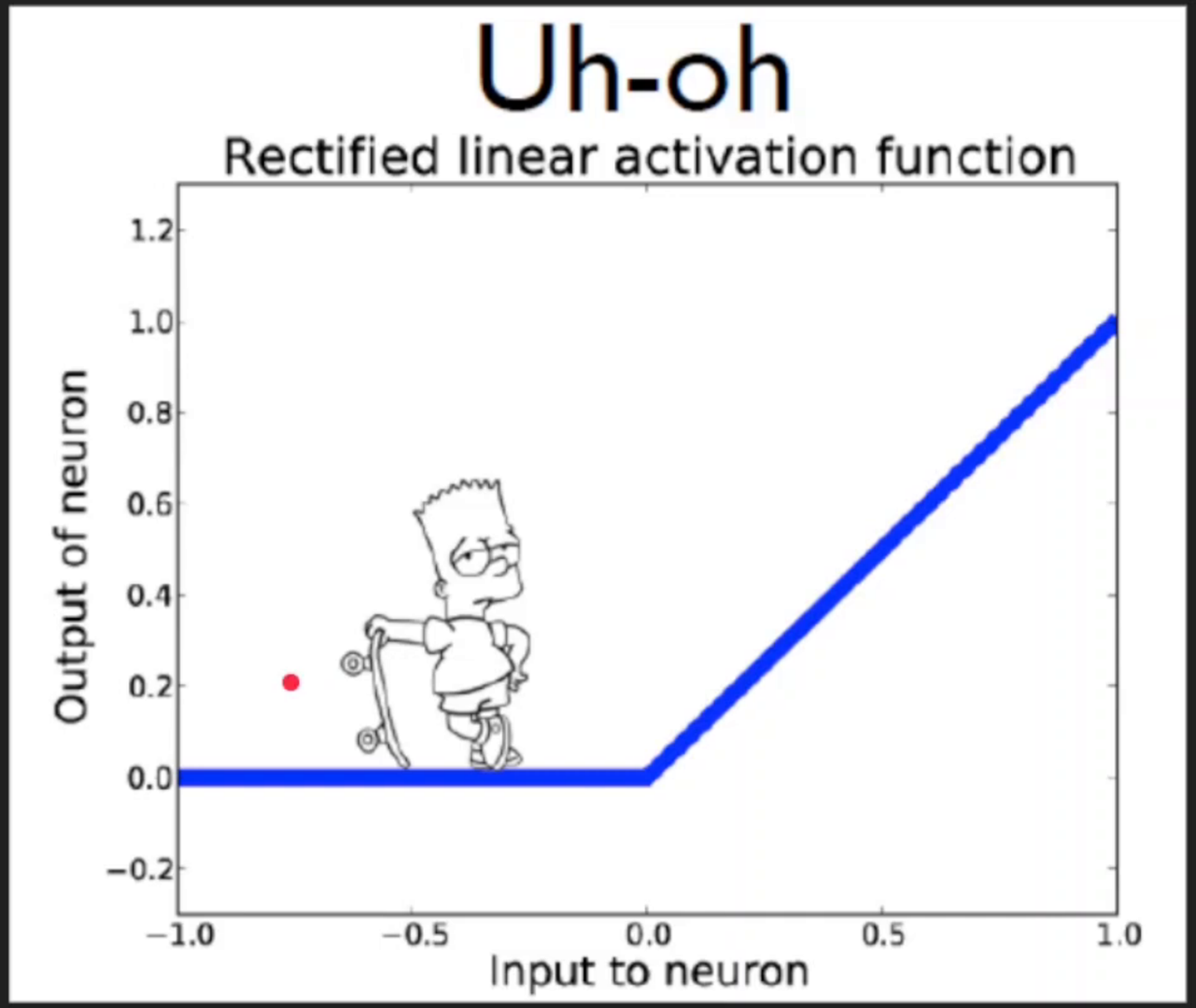
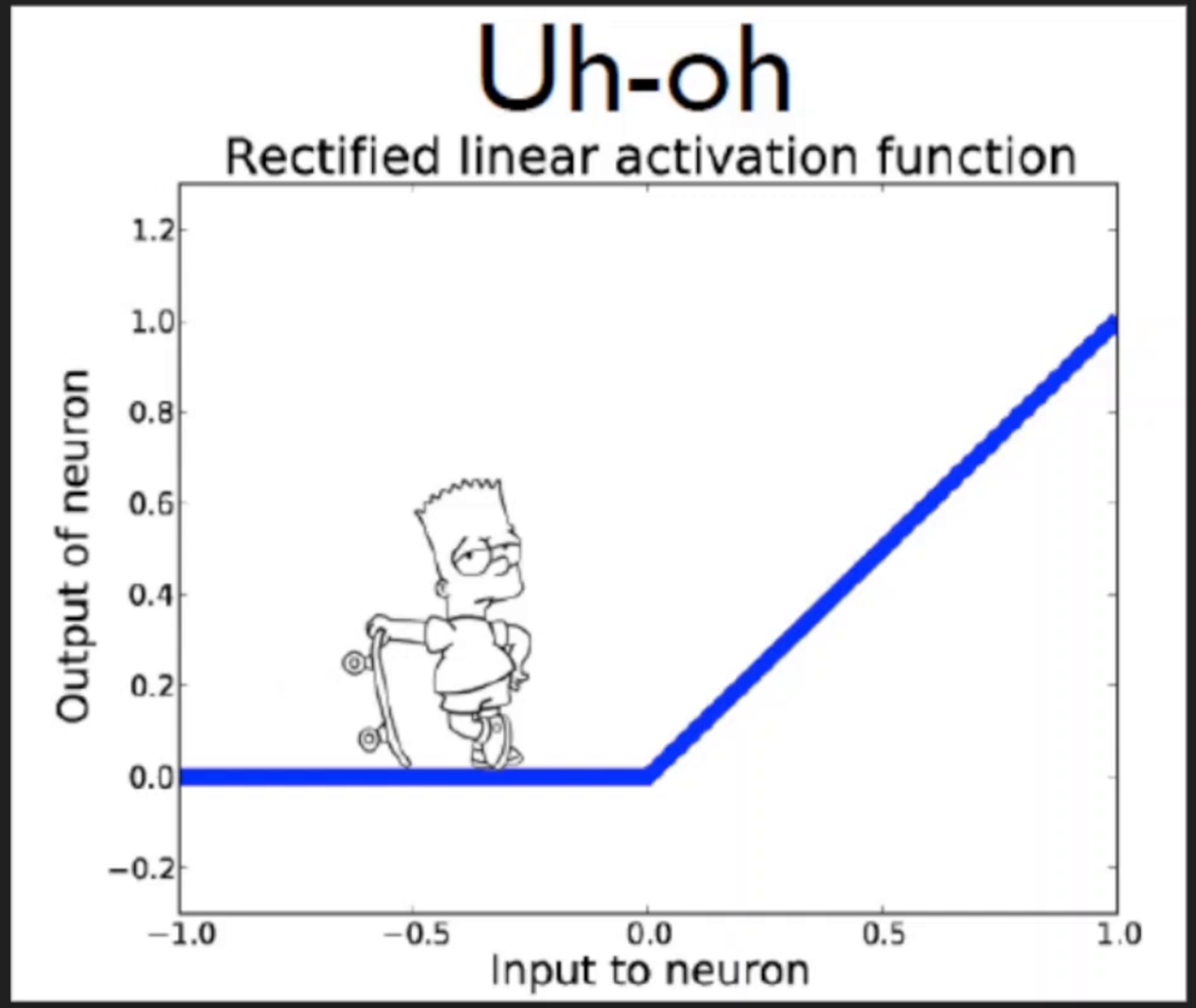


# Dead Neurons

$$Y = \mathrm{ReLU}(W*X + b)$$



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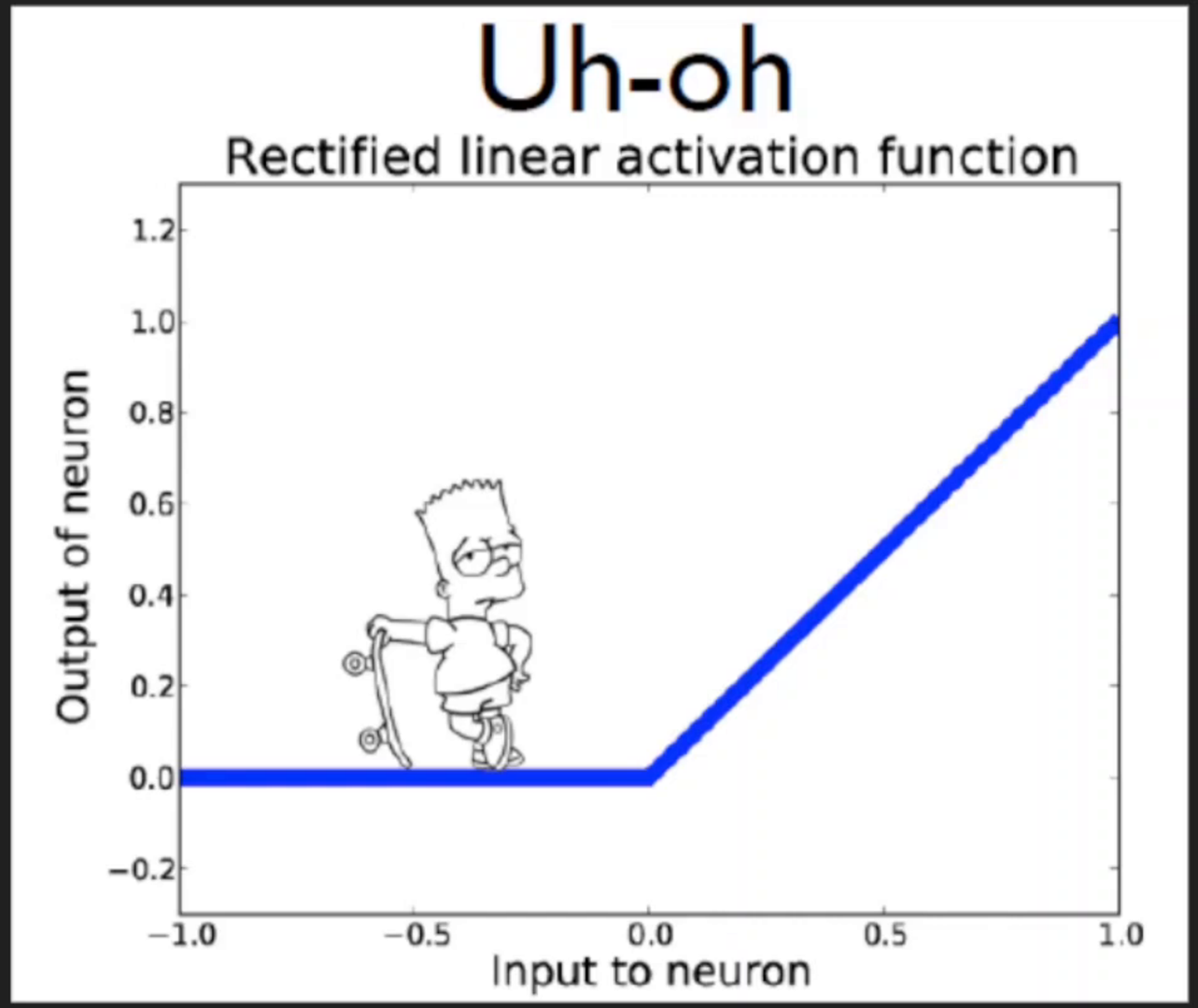

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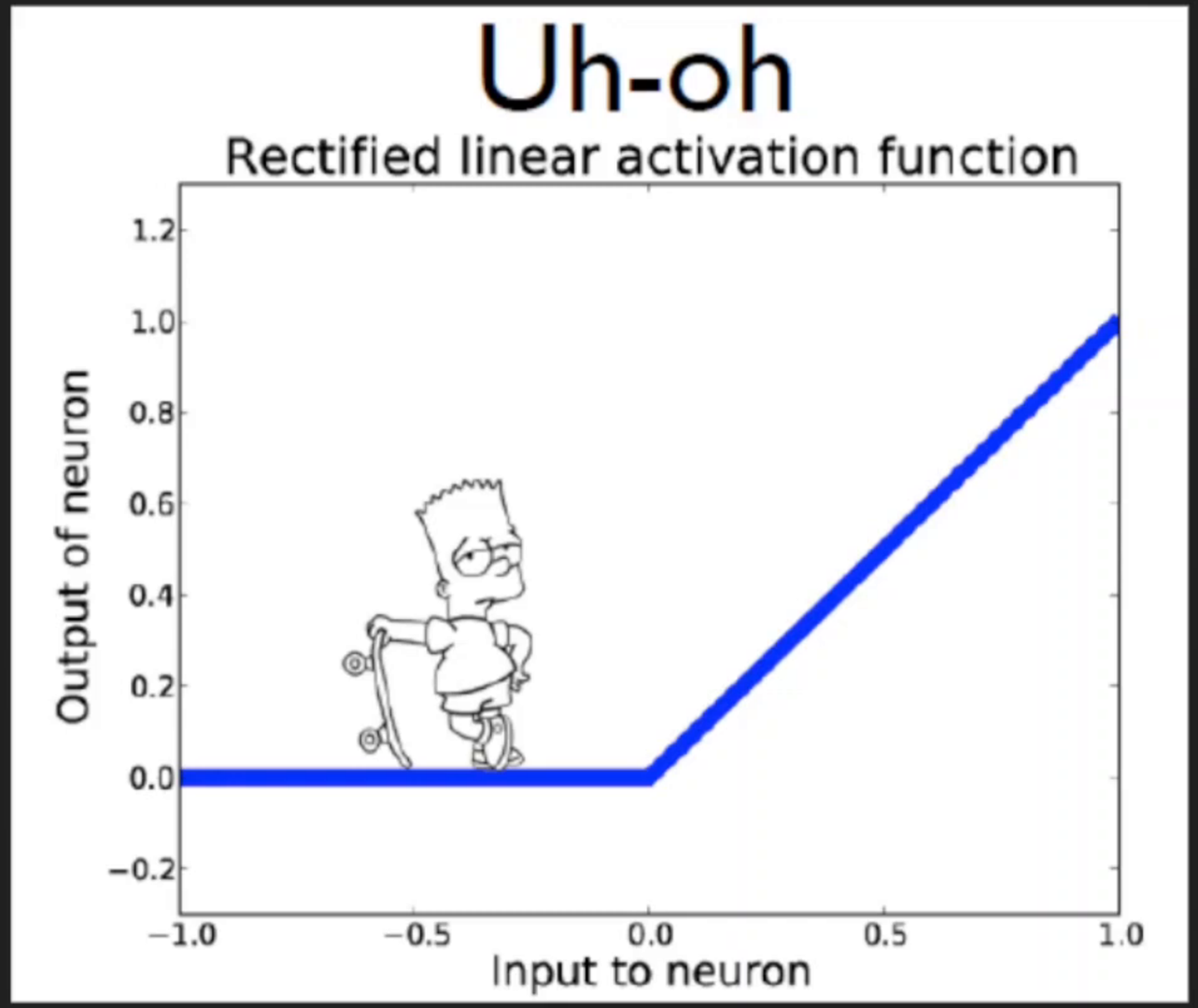

# Advantages

- Computationally Simple
- Representational Sparsity
- Linear Behaviour
- Train deeper networks

$$ReLU$$

$$f(x) = max\,(0, x)$$

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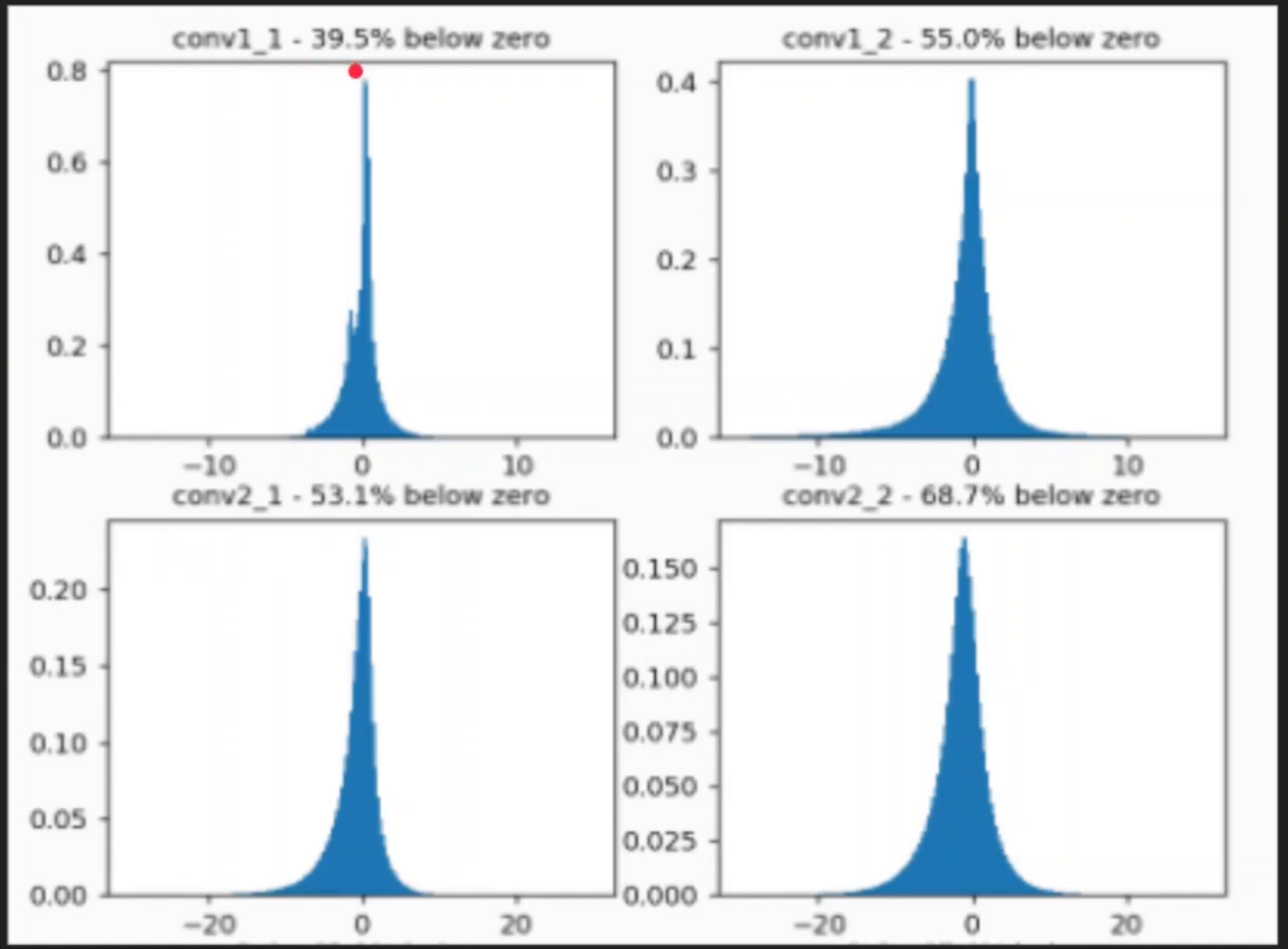

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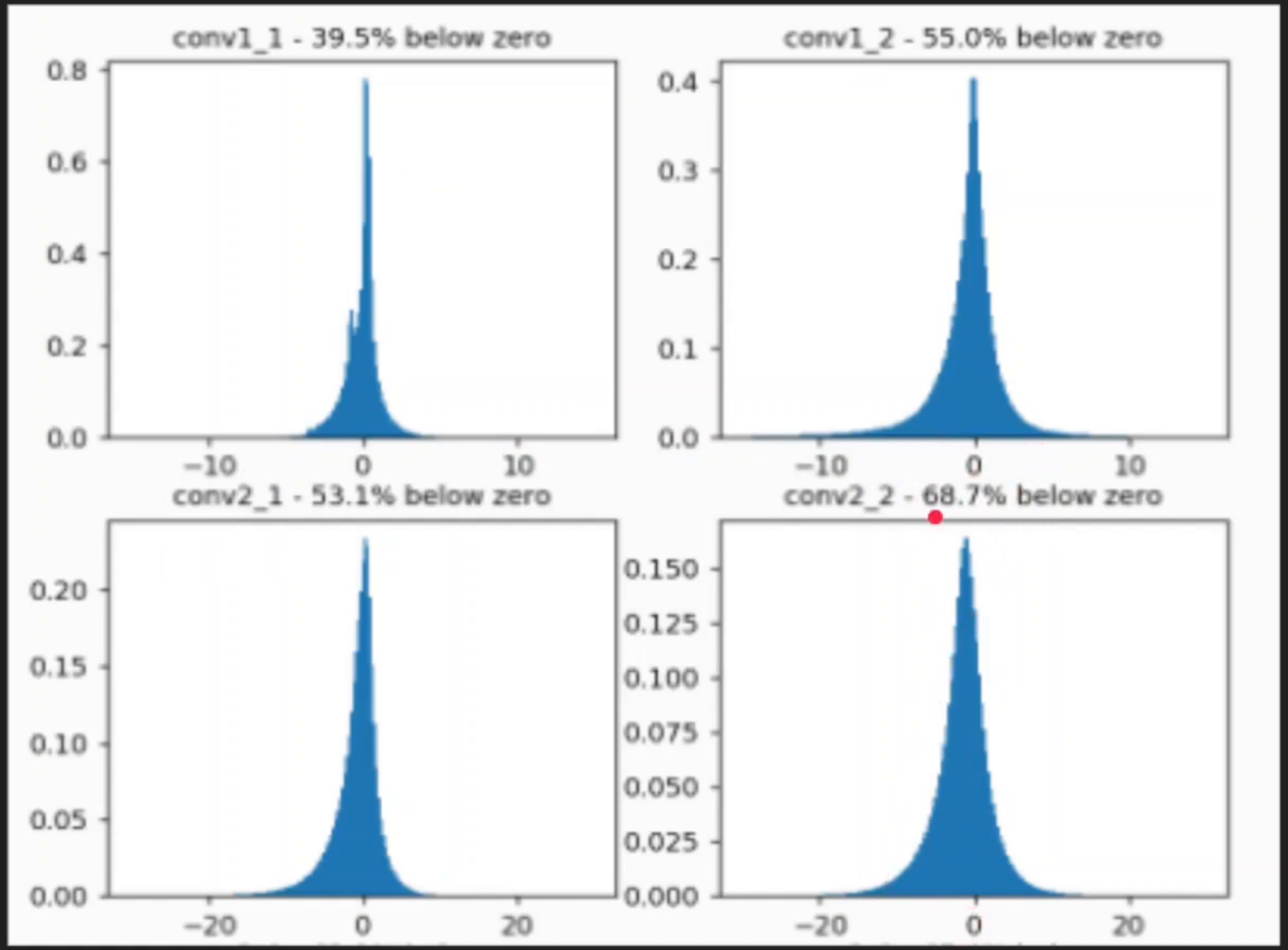

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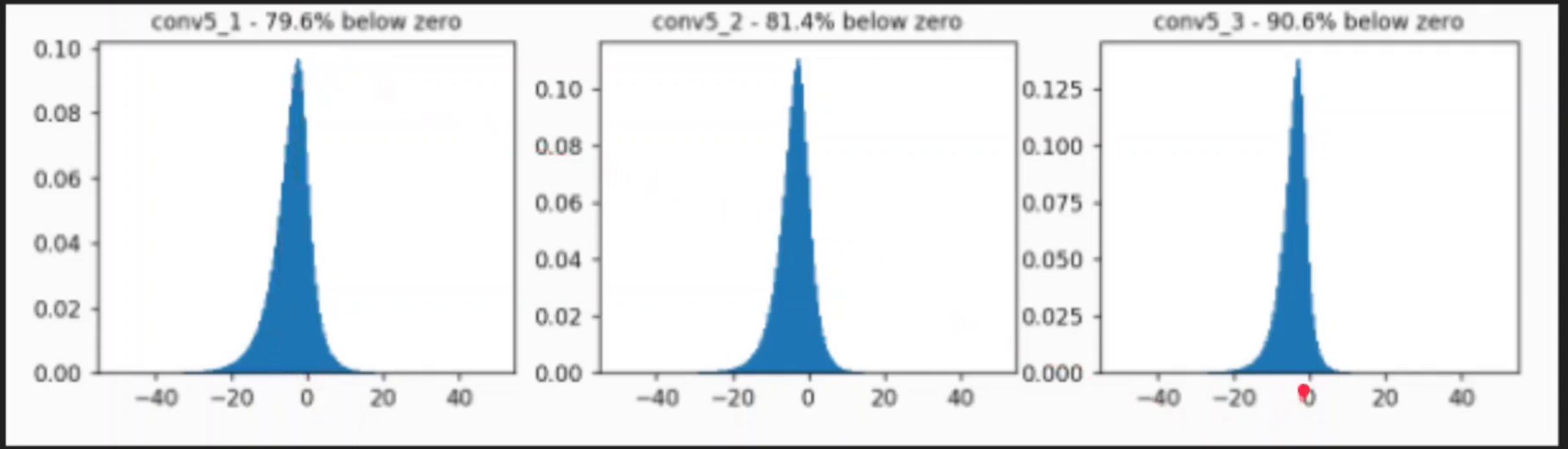

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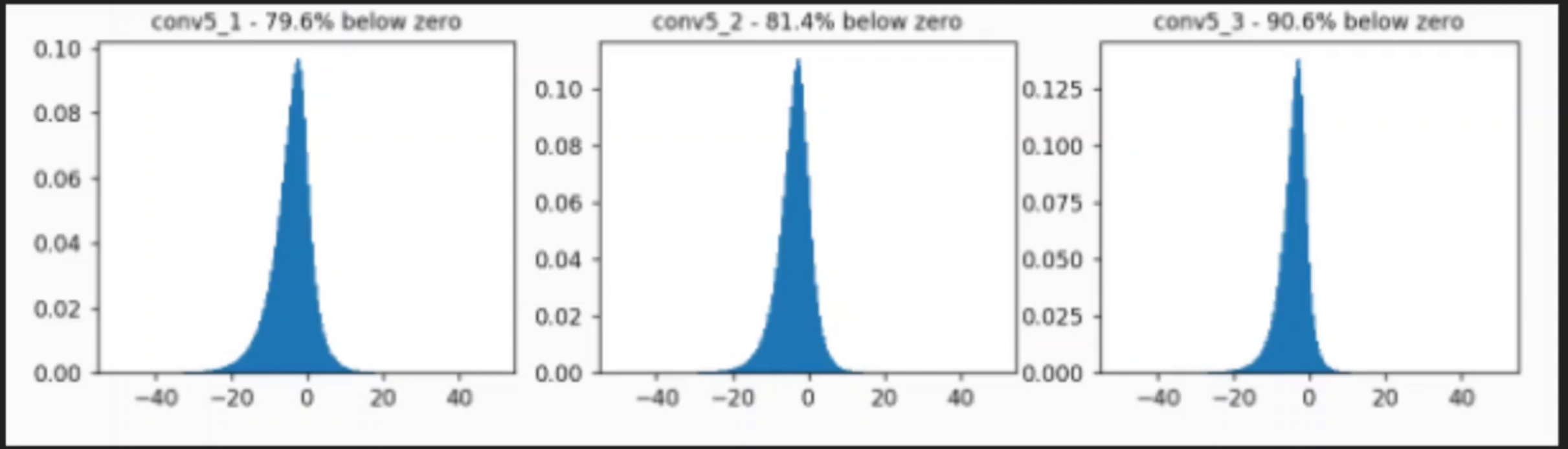

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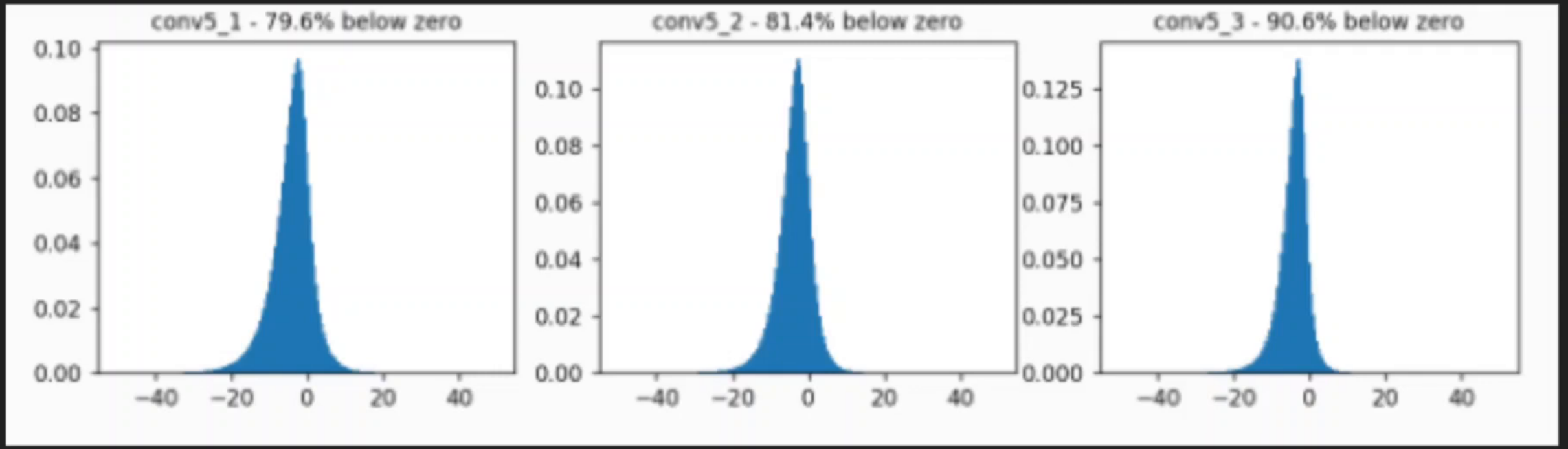

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$$W_{new} = W_{old} - \eta \Delta W$$

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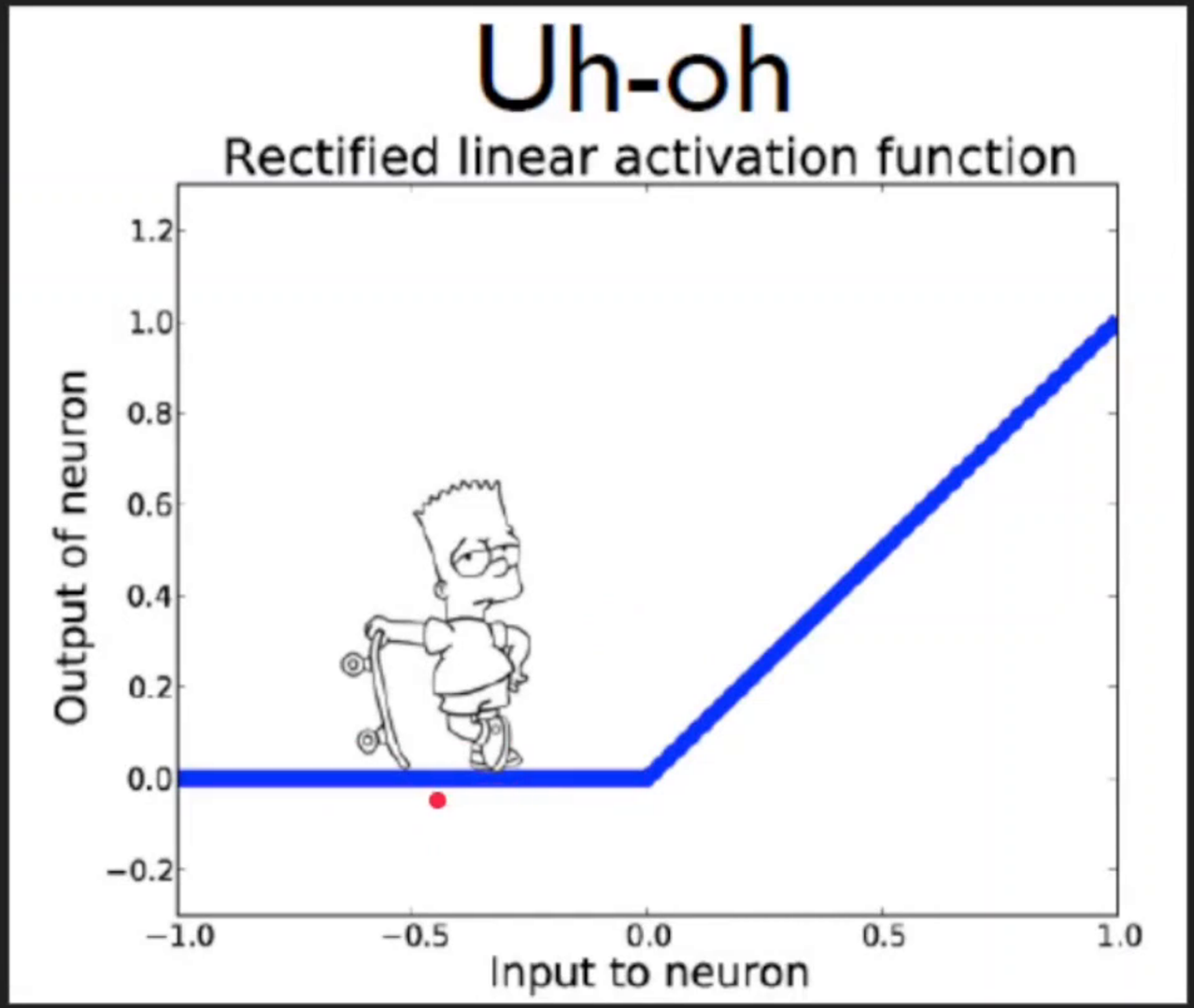

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- Exploding Gradient
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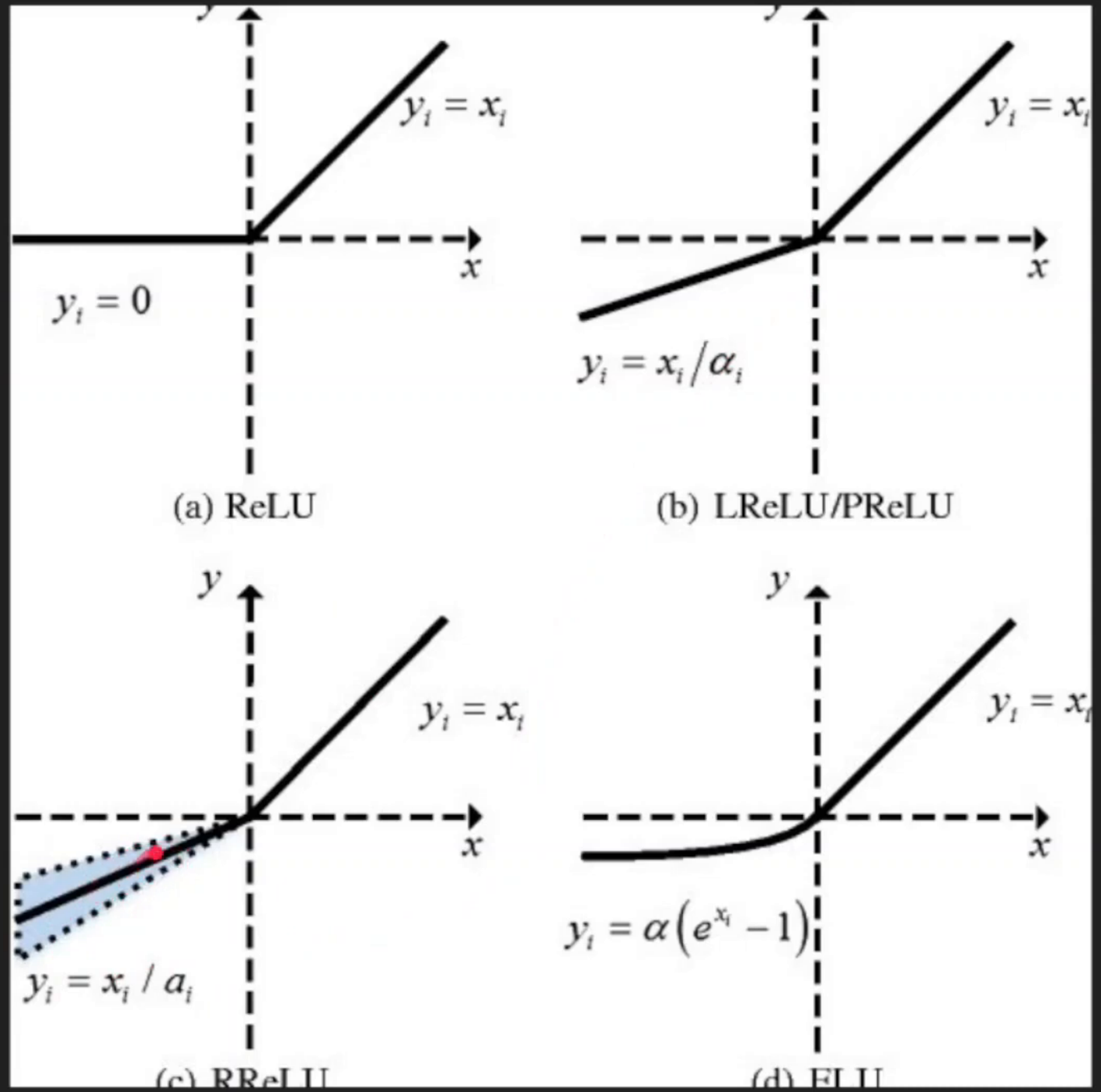

# Tips

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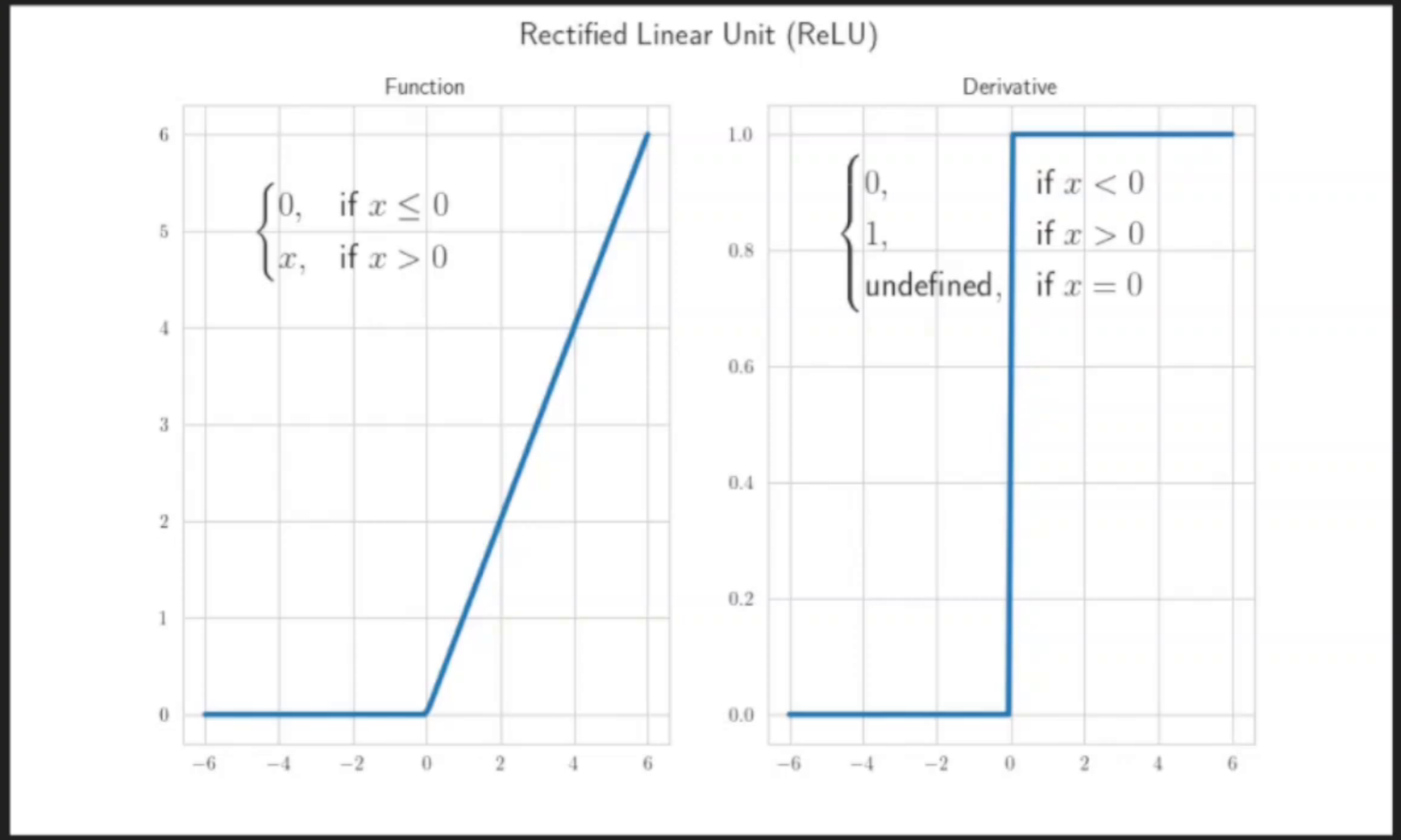
- Scale input data
- Weight penalty

# Python Implementation

```
def relu(x):
    return max(0,x)
```

**Derivative:**

```
    if x>0:
        return 1
    else:
        return 0
```



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