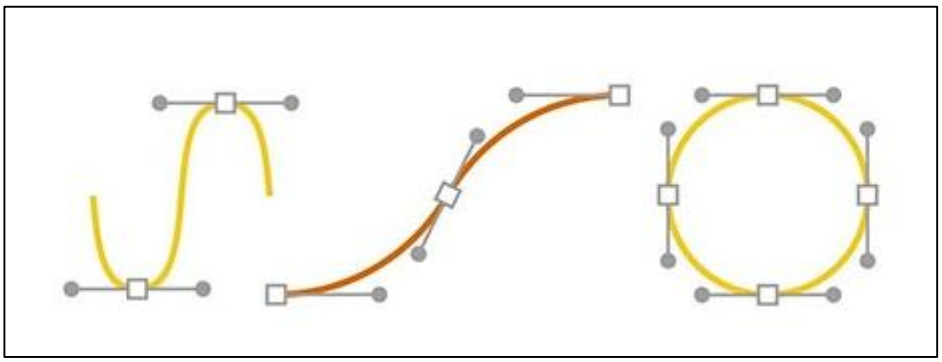
Types of Computer Graphics

There are two types of computer graphics:

- **Vector Graphics**

  These graphics consist of anchored dots and connected by lines and curves, similar to the connect-the-dot activities you may have done as a kid. Also, vector graphics are made up of paths, each with a mathematical formula (vector) that tells the path how it is shaped. Because these graphics are not based on pixels, they are known as resolution independent, which makes them infinitely scalable. Their lines are sharp, without any loss in quality or detail, no matter what their size. These graphics are also device-independent, which means their quality doesn't depend on the number of dots available on a printer or the number of pixels on a screen. Because they consist of lines and anchor points, the size of the files are relatively small. This makes vector files the best format for graphic assets such as illustrations, icons and company logos, as the same file can be used for designs ranging from a mobile app to a large billboard without sacrificing quality or increasing file size.

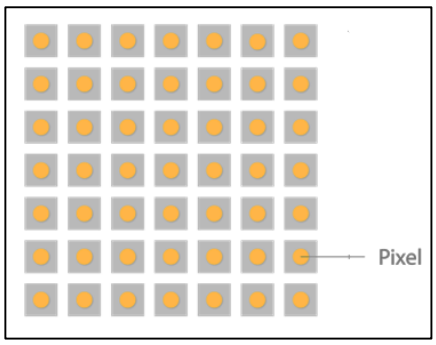


Vector shapes are made up of points and lines that create paths.

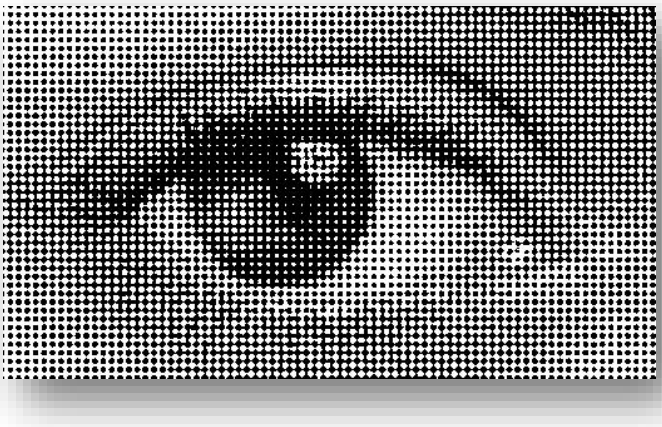
Vector image

- **Raster Graphics**

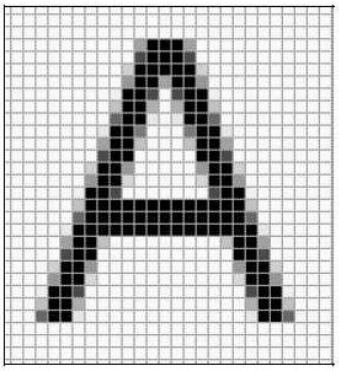
  Raster graphics, also called bitmap graphics, a type of digital image that uses tiny rectangular pixels, dots, or picture elements, arranged in a grid formation to represent an image. Raster is good for photographs. Raster graphics are great when creating rich and detailed images. Every pixel in a raster image can be a different color creating a complex image with all kinds of color and variations.



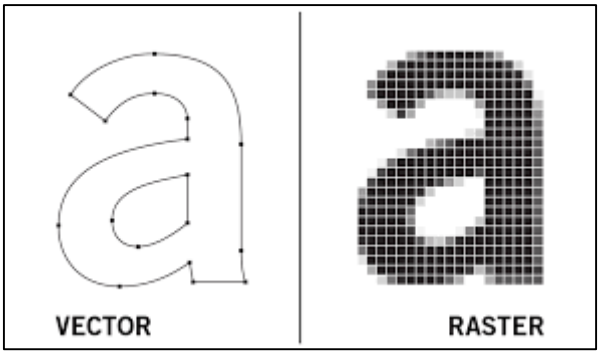
Computer screen with pixels is a raster



Computer screen with pixels is a raster

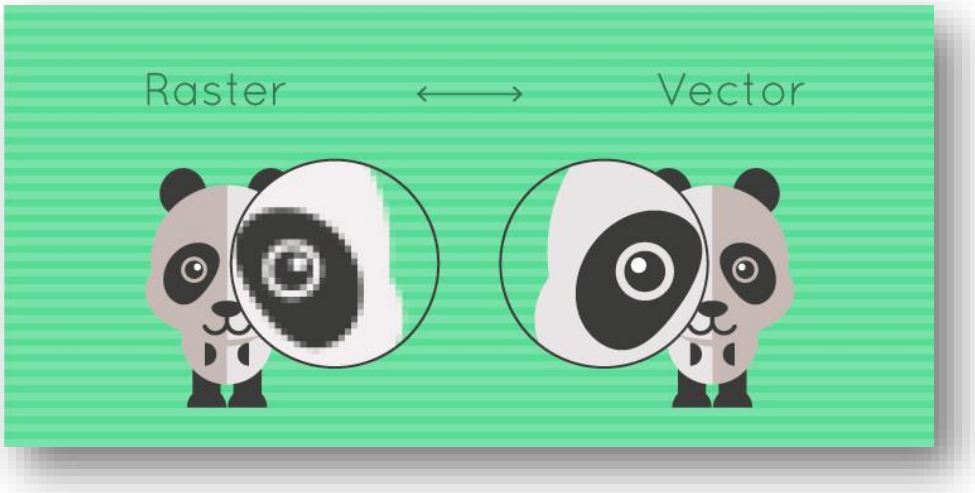


Computer screen with pixels is a raster



Raster image Vs Vector image

When the raster image is zoomed in or enlarged pixels appear like little squares on graph paper. Note the figure below. **We will deal with Raster Graphics**.



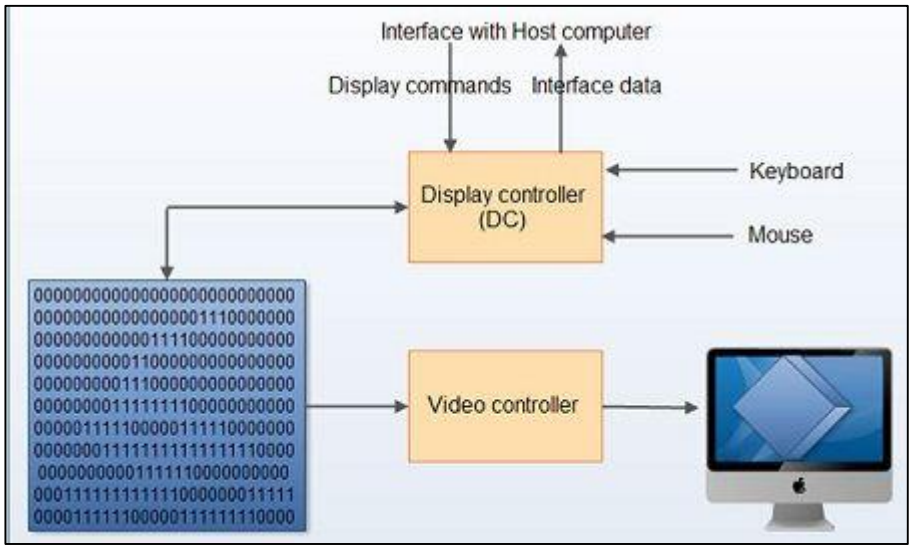
Raster image Vs Vector image

Note: It is known that Raster graphics is more popular than Vector graphics, but if your project requires scalable shapes and solid colors, vector is the best choice, but if your project requires complex color blends, raster is the preferred format.

Graphics Display System

It consists of four components:

1. **A display controller** that gets the inputs and commands from the user and determines the image to be displayed on the monitor. The display controller will divide the image into a number of pixels. This image which is to be displayed is stored in the frame buffer. The image will be stored as a matrix of intensity values.
2. **A digital memory** (frame buffer or Bitmap), in which the displayed Image is stored as a matrix of intensity values. The number of rows in the frame buffer array equal the number of raster lines on the display screen, and the number of columns in this array equals the number of pixels on each raster line.
3. **A monitor** (computer screen).
4. **Video controller** which is a simple interface that passes the contents of the frame buffer to the monitor. Inside the frame buffer the image is stored as a pattern of binary digital numbers, which represent a rectangular array of picture elements, or pixel. In the Simplest case where we wish to store only black and white images, we can represent black pixels by 0's in the frame buffer and white Pixels by 1's. The display controller simply reads each successive byte of data from the frame buffer and converts each 0 and 1 to the corresponding video signal. This signal is then fed to the monitor. If we wish to change the displayed picture all we need to do is to change of modify the frame buffer contents to represent the new pattern of pixels.



Graphics Display System.

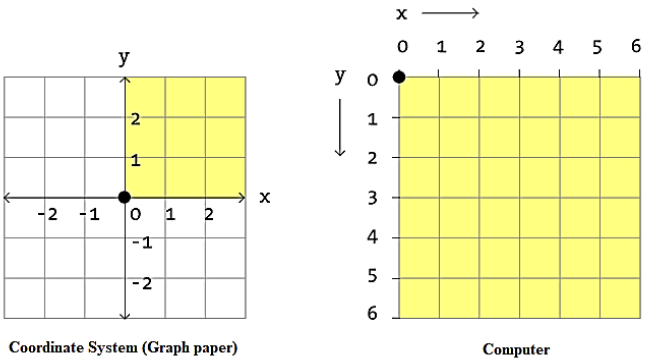
Note: A video controller, often referred to as a video or graphics card, is a key hardware component that allows computers to generate graphic information to any video display devices, such as a monitor or projector. Some modern computers do not include video cards, but rather have graphics processing units directly integrated into the computer's motherboard.

Scan Conversion Definition

It is a process of representing graphics objects a collection of pixels. The graphics objects are **continuous**. The pixels used are discrete. Each pixel can have either on or off state. The circuitry of the **video display device** of the computer is capable of converting binary values (0, 1) into a pixel on and pixel off information. 0 is represented by pixel off. 1 is represented using pixel on. Using this ability graphics computer represent picture having discrete dots. Any model of graphics can be reproduced with a dense matrix of dots or points. Most human beings think graphics objects as points, lines, circles, ellipses. For generating graphical object, many algorithms have been developed. The process of **scan conversion** is also called as **rasterization**. The algorithms implementation varies from one computer system to another computer system. Some algorithms are implemented using the software. Some are performed using hardware or firmware. Some are performed using various combinations of hardware, firmware, and software.

Coordinates of Computer Screen

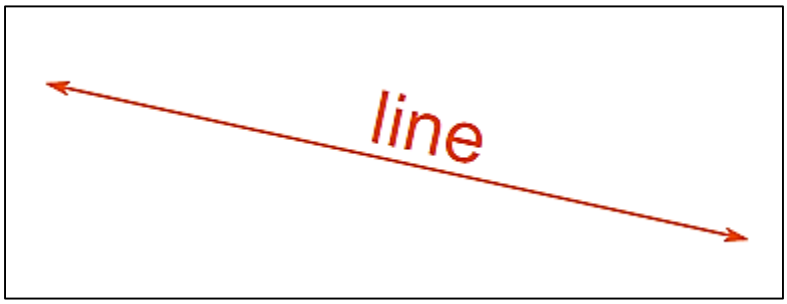
The graph paper ("Cartesian coordinate system") placed (0, 0) in the center with the y-axis pointing up and the x-axis pointing to the right (in the positive direction, negative down and to the left). The coordinate system for pixels in a computer window, however, is reversed along the y-axis. (0, 0) can be found at the top left with the positive direction to the right horizontally and down vertically.



Coordinates System (Graph Paper) Vs Coordinates of Computer Screen.

Line

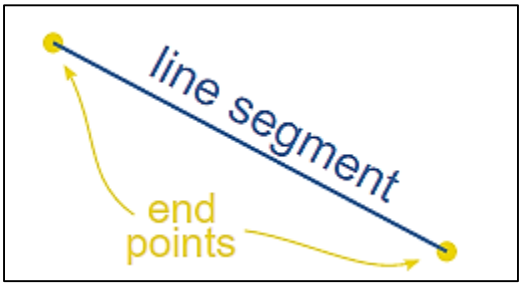
Line is straight (no bends), has no thickness, and extends in both directions without end (infinitely).



One end makes it a "Ray", and two ends makes it a "Line Segment".

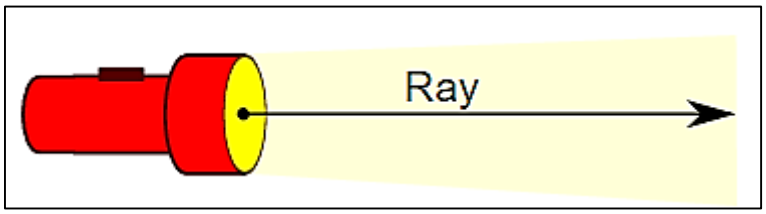
Line Segment

When it does have ends it is called a "Line Segment".



Ray

When it has just one end it is called a "Ray"

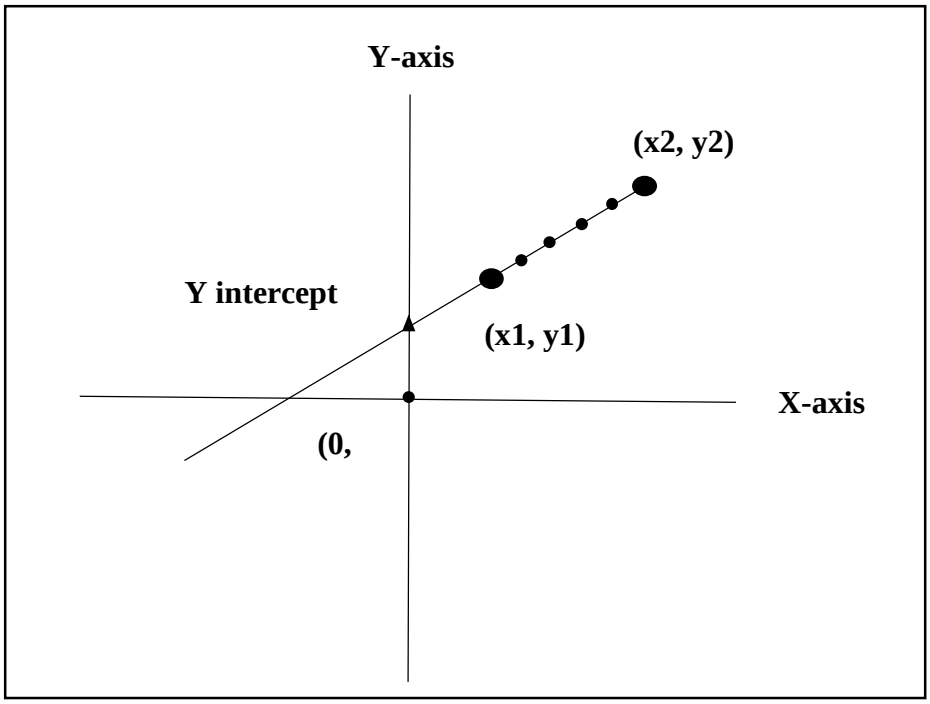


Equation of Straight line

The equation of a straight line is usually written as this way:

$$Y = mX + C$$

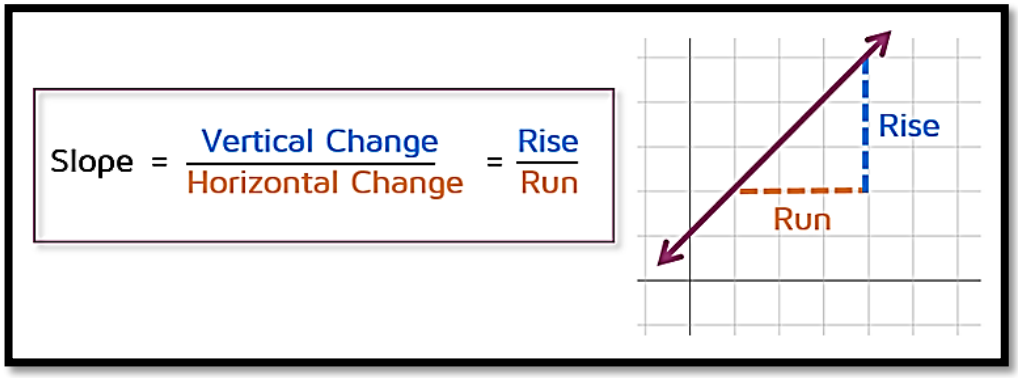
Where, **m** is the Gradient or Slope of a line, **C** is the intercepting point (line segment intercepts Y-axis when X=0), see the figure below:



If you know values of **m** and **c** you can find any point on line segment. There are different equations of a line but the above equation is specially used in computer graphics.

Slope

Slope measures the steepness of a line. **Slope** also tells us the direction of the line - if it goes up, down, or if it's horizontal or vertical. **Slope** is calculated as the ratio of the amount of vertical change to horizontal change.



m (slope)= $\frac{\Delta y}{\Delta x}$, where $\Delta x = x2 - x1$, $\Delta y = y2 - y1$

Ex: find the slope of a line, which has these two end points **(8, 8)** and **(20, 15)**.

$\Delta x = x2 - x1$

$\Delta x = 20 - 8$

$\underline{\Delta \boldsymbol{x} = \mathbf{12}}$

$\Delta y = y2 - y1$

$\Delta y = 15 - 8$

$\underline{\Delta \boldsymbol{y} = \mathbf{7}}$

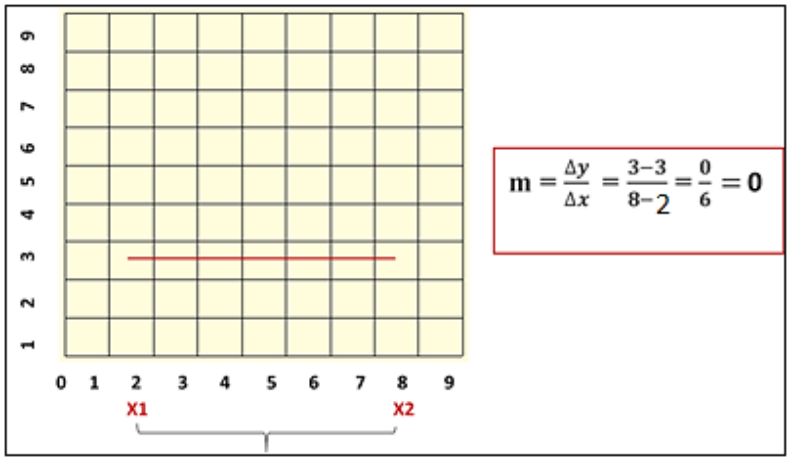
m (slope)= $\frac{\Delta y}{\Delta x}$

m = $\frac{\mathbf{7}}{\mathbf{12}}$ = 0.6

There are four different types of slope, depending on the direction of the line (zero, undefined, positive (m<1, m=1, m>1), negative).

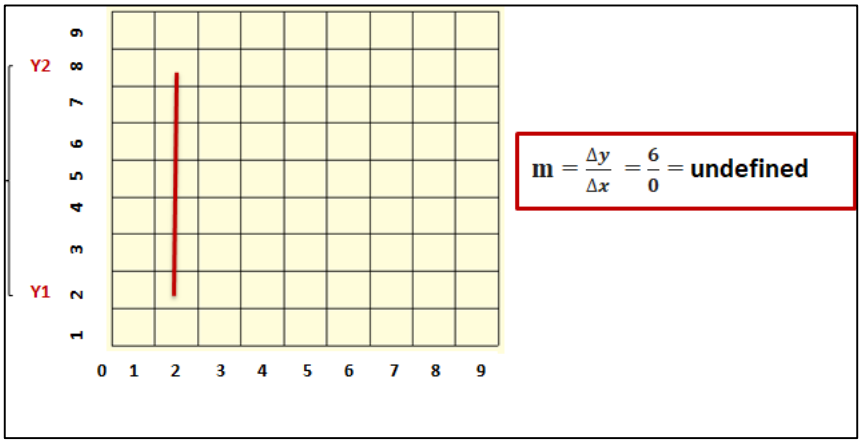
1- Slope of Zero

If the y-values are not changing as x increases, the line will have a slope of 0. Anytime the line is horizontal (flat from left to right), the slope is zero.



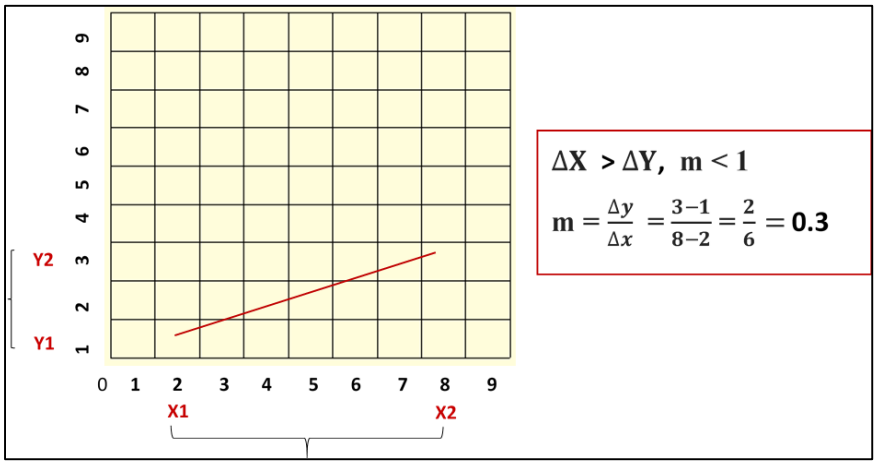
2- Undefined Slope

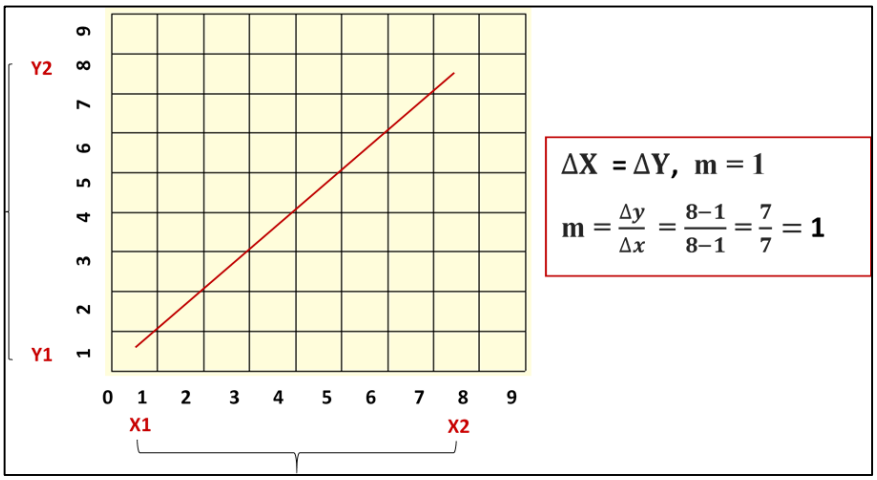
A vertical line has an undefined slope. In this situation, the y-values are changing, but the x-value always stays the same. If you look at the definition of slope, the amount of horizontal change is in the denominator of a fraction. In math, you can't have a 0 in the denominator. It doesn't make sense to divide by 0 so we say that the slope of a vertical line is undefined. There isn't a slope for these types of lines.

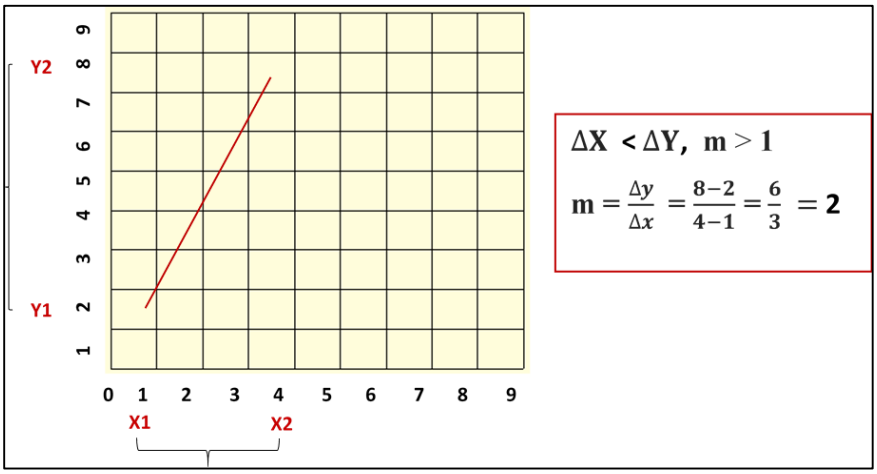


3- Positive slope (m<1, m=1, m>1)

A positive slope means that two variables are positively related that is, when x increases, so does y, and when x decreases, y decreases also.

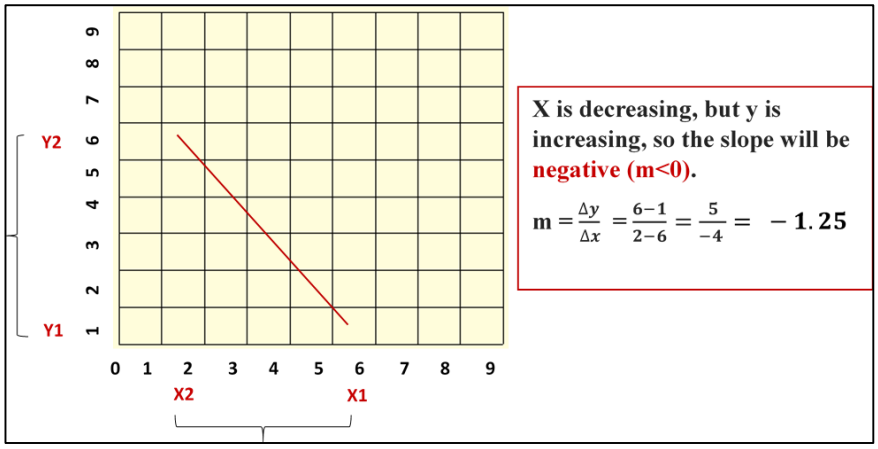






4- Negative slope

A negative slope means that two variables are negatively related; that is, when x increases, y decreases, and when x decreases, y increases.



Useful summery

The concept of slope is very useful, because it measures the relationship between two variables. A **positive slope** means that two variables are positively related that is, when x increases, so does y, and when x decreases, y decreases also. Graphically, a positive slope means that as a line on the line graph moves from left to right, the line rises.

A **negative slope** means that two variables are negatively related; that is, when *x* increases, *y* decreases, and when *x* decreases, *y* increases. Graphically, a negative slope means that as the line on the line graph moves from left to right, the line falls.

Slope and Angle of a line

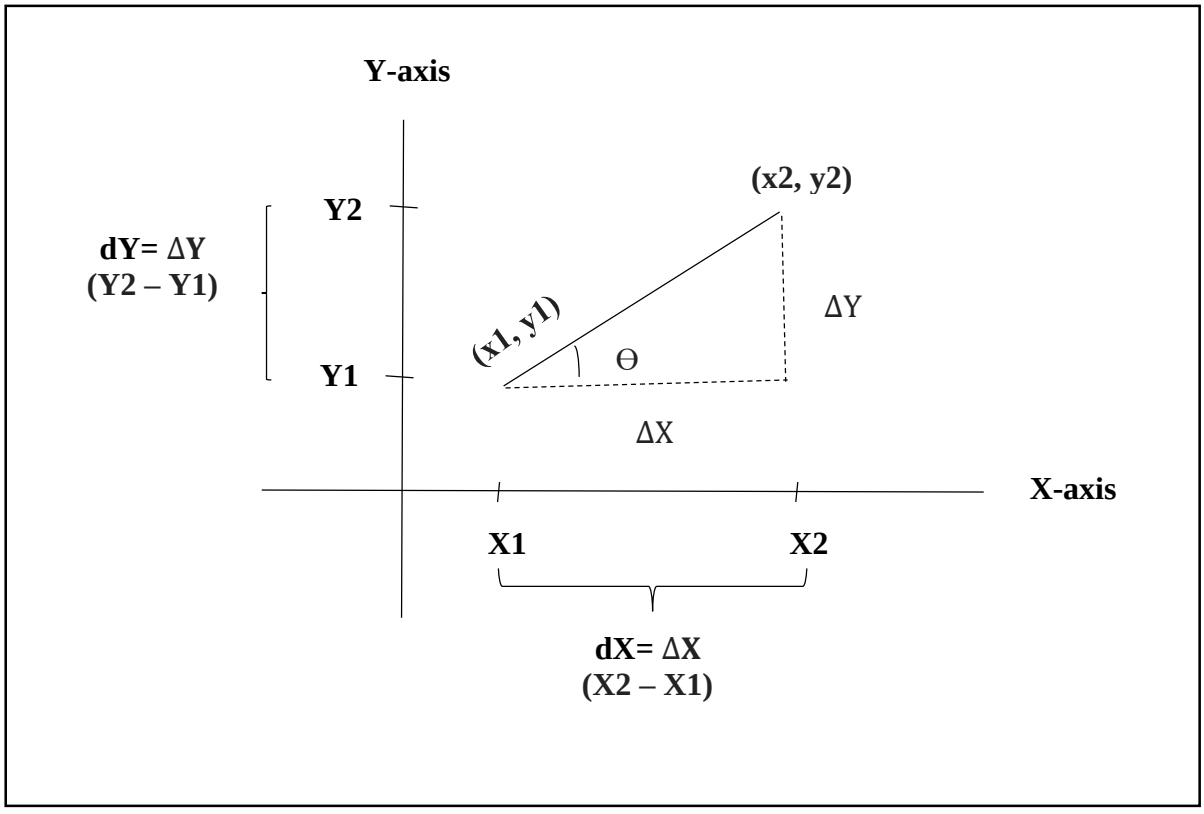
In the figure below, a line segment has two end-points (x1, y1) and (x2, y2). The dotted line that labeled ΔX is the difference between x2 and x1, and the dotted line that labeled ΔY is the difference between y2 and y1. These three sides make traingle with Θ angle. As we mentioned before, **Slope** is calculated as the ratio of the amount of vertical change to horizontal change.

$$\textbf{m (slope)}= \frac{\Delta y}{\Delta x}$$

ΔY is the opposite side of Θ angle and ΔX is the adjacent side of Θ angle. Tangent of an angle is the length of opposite side divided by the length of the adjacent side:

$$\textbf{Tan}(\Theta) = \frac{\textbf{opposite side}}{\textbf{adjacent side}} = \frac{\Delta y}{\Delta x} = \textbf{m (slope)}$$

So, **Tan(Θ) = m (slope)**.

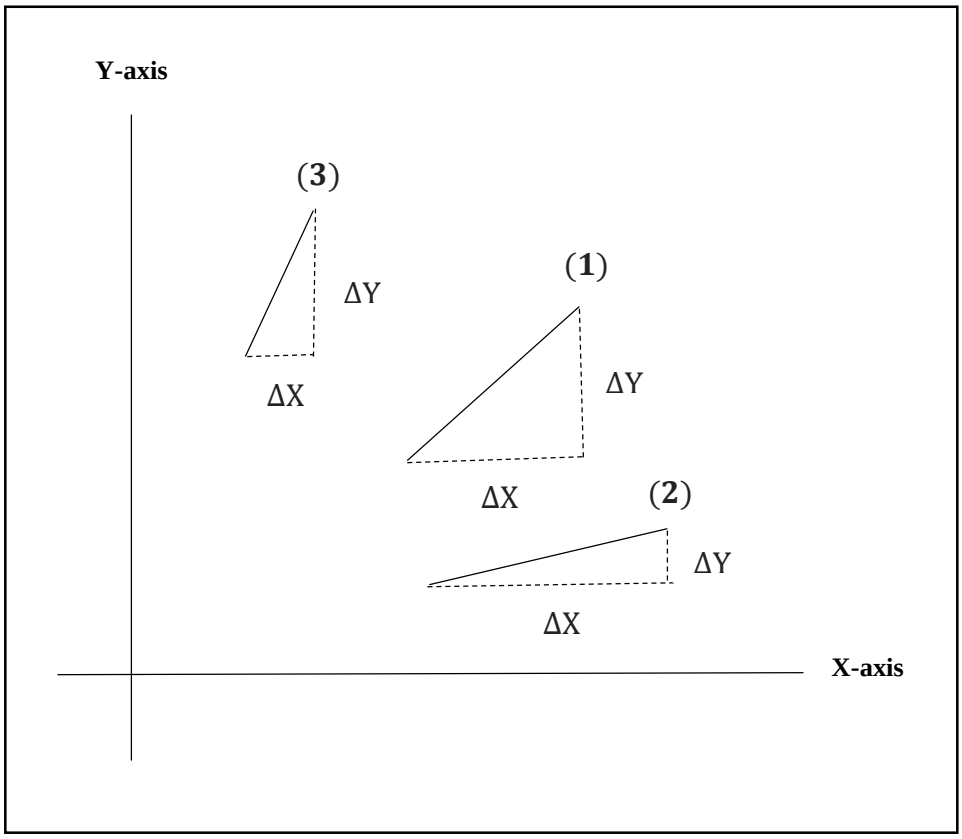


You know that Tan(45) = 1, so:

1- When a line sloped at 45 angle, then a slope will become equal to **one** (m =1). Where ΔY = ΔX.

2- When a line sloped at an angle of less than 45 degree, then a slope will become less than **one** (m < 1). Where ΔY < ΔX.

3- When a line sloped at an angle of greater than 45 degree, then a slope will become greater than **one** (m > 1). Where ΔY > ΔX.



Sampling

Any line that we draw on the two dimensional coordinates system, must be represented by an equation. The line equation is Y=mX + C, where m is the slope of a line and C is the intercepting point of a line with y-axis when X=0. Sampling process means that, in line equation we substitute the value of X to get Y or vice versa. Sampling process of a line equation depends on **the greatest value** of **Δx** or **Δy**.