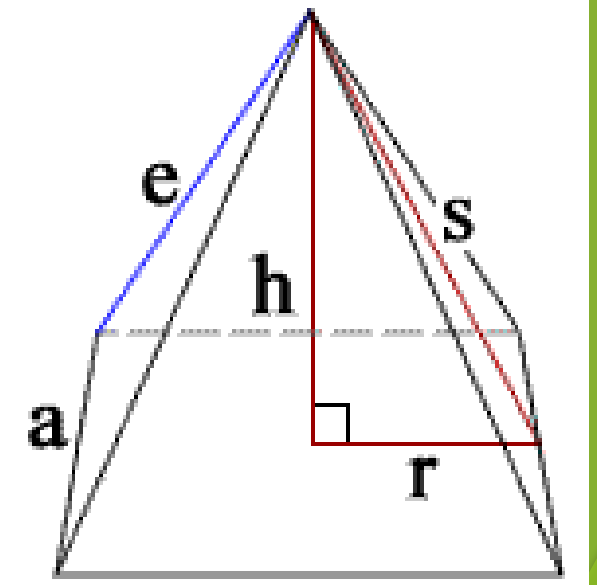


# Lecture 05

**Mathematics in Computer Science**

# What is mathematics?

- ▶ Mathematics is defined as the science which deals with logic of shape, quantity and arrangement.
- ▶ During ancient times in Egypt, the Egyptians used math's and complex mathematic equations like geometry and algebra. That is how they managed to build the pyramids.
- ▶ Mathematics is basically related to understanding structure.
- ▶ It is used to do logical analysis, make relevant calculations and eventually to deduce conclusions and pattern.



# Role of Math in CS

- ▶ What is the importance of the ground in building?
- ▶ If you don't have an understanding of the foundation on which you place a structure, that structure may be fairly wobbly and will fail over time.
- ▶ Same is the case here with Computer Science

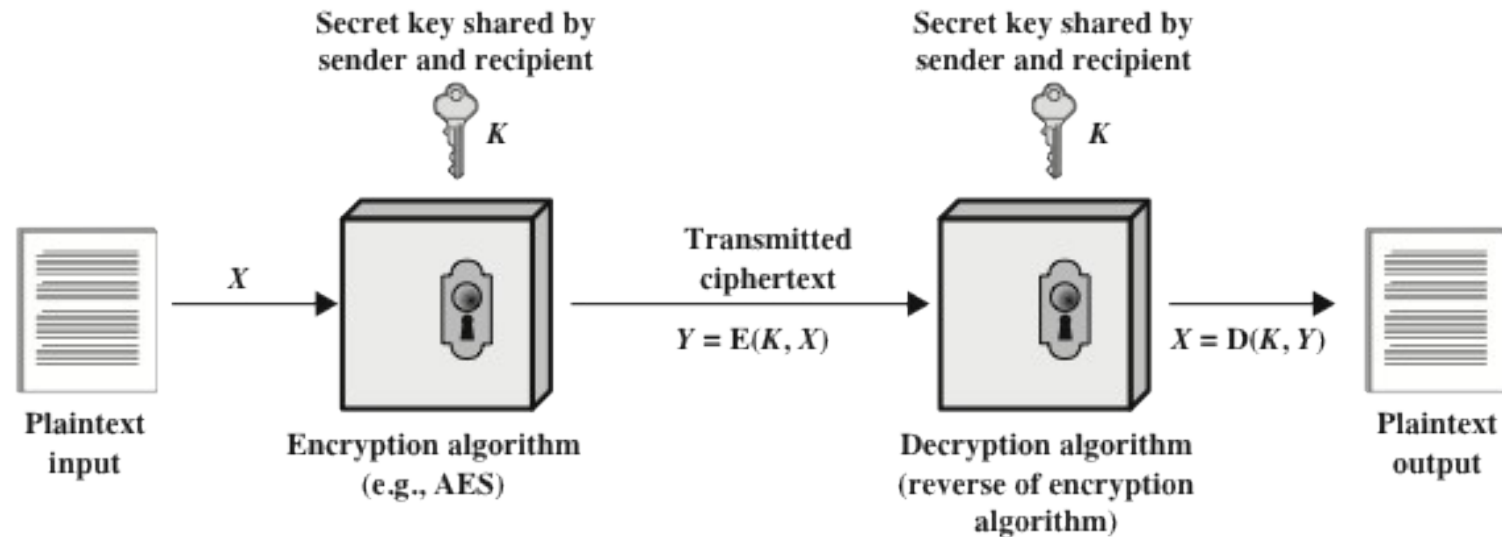
## Mathematics is prominent at every layer of Computing:

- ▶ The lowest layer with ALU performing the Arithmetic and logical operations.
- ▶ The middle layer with Operating system making use of mathematics and algorithms for process management, memory management, disk management, networking operations and more.
- ▶ The upper layer with all sort of application and system software using all sort of algorithms to create all sort of magic.
- ▶ Right now, when you are reading *this* text, there is mathematics going on behind the scenes to render it on your screen taking into account specific **font face/size/color/monitor's X,Y coordinates** etc. with different algorithms contributing to the final result.

# Mathematics applications

# Mathematics in Cryptography

- Cryptography is a method of storing and transmitting data in a **particular form** so that only those for whom it is intended can read and process it.



**Plain Text:** meet me after the toga party

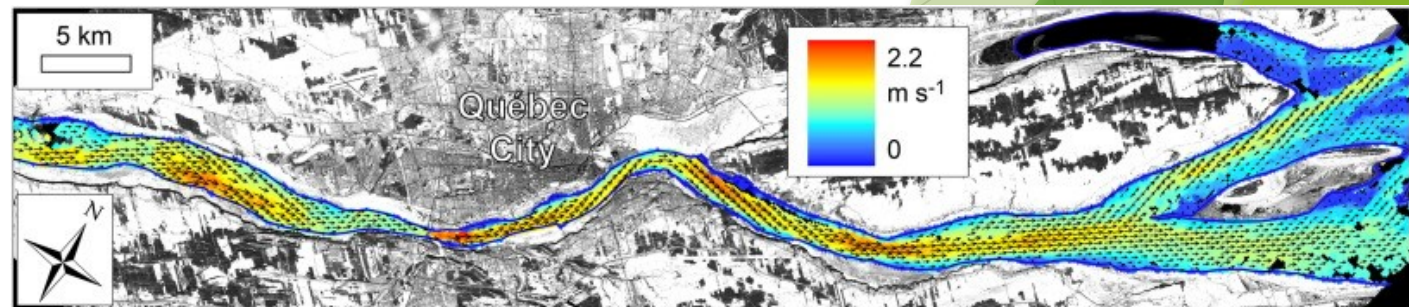
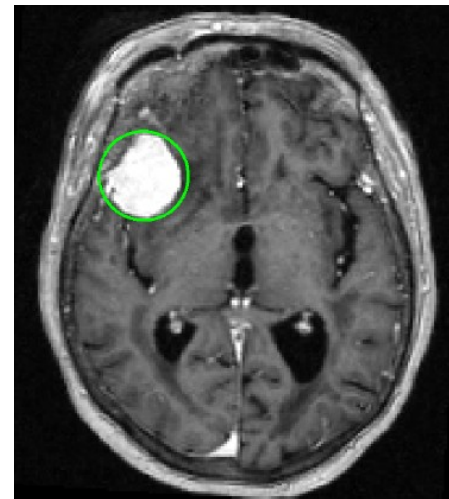
**Cipher:** PHHW PH DIWHU WKH SDUWB

Each element is shifted 3 times to the right

# Image Processing & Computer Vision

- ▶ Detecting/tracking Hurricanes
- ▶ Cancer/Tumor Detection
- ▶ Anomaly Detection
- ▶ Movement detection from satellite images
- ▶ ...and many more

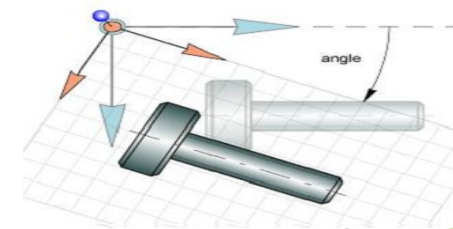
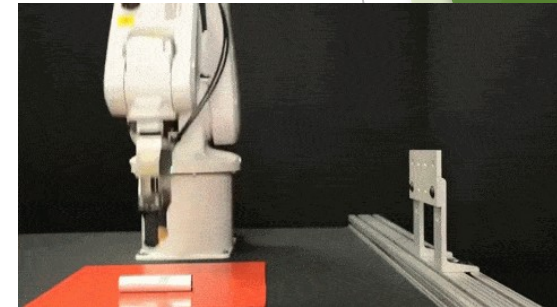
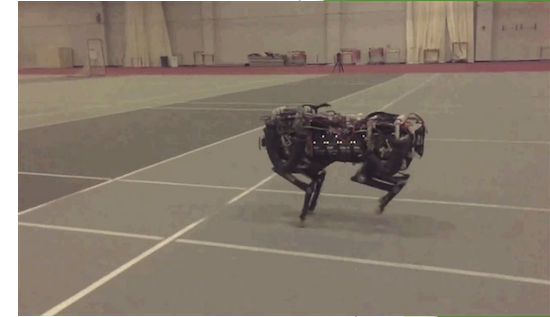
All these applications required heavy mathematical operations



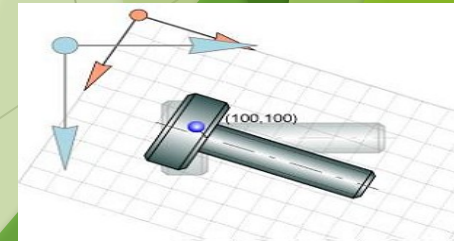


# Robotics

- ▶ In robotics 3D linear and rotational motion are involved
- ▶ Understanding of different coordinate systems are necessary to describe position
  - ▶ Coordinates to describe position.
    - ▶ rectangular  $(x,y,z)$
    - ▶ cylindrical  $(r, \theta, z)$
    - ▶ spherical  $(r, \theta, \phi)$
- ▶ Similarly pose estimation and object holding required complex maths



Simple rotation

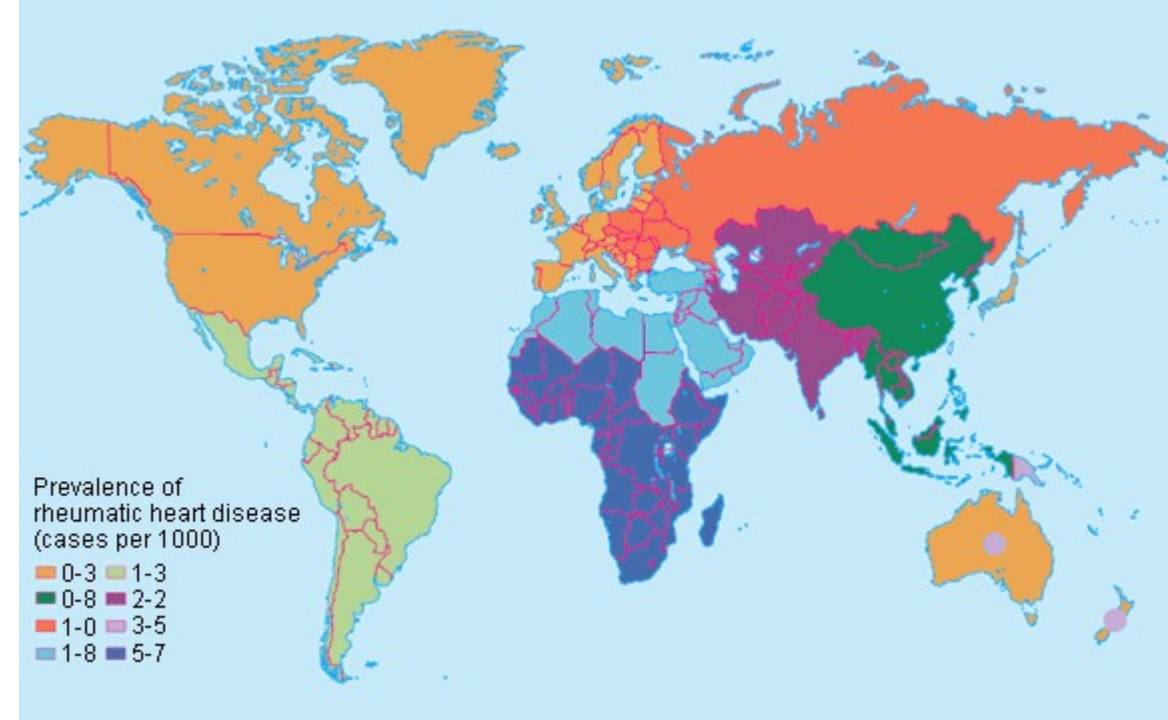


Rotation & translation



# Epidemiology

- ▶ Epidemiology is the branch of medicine which deals with the incidence, distribution, and possible control of diseases and other factors relating to health.
- ▶ What is your heart rate now? How you measure it? **100 beats/min**
- ▶ How smart devices measure blood pressure, heart rate and sugar?
- ▶ How the computerized eye-sight checking machine (Auto-Refractometer) works?
- ▶ All these techniques required math at backend.



# Math in CS

## Civil Engineering Apps



### Civil Engineering

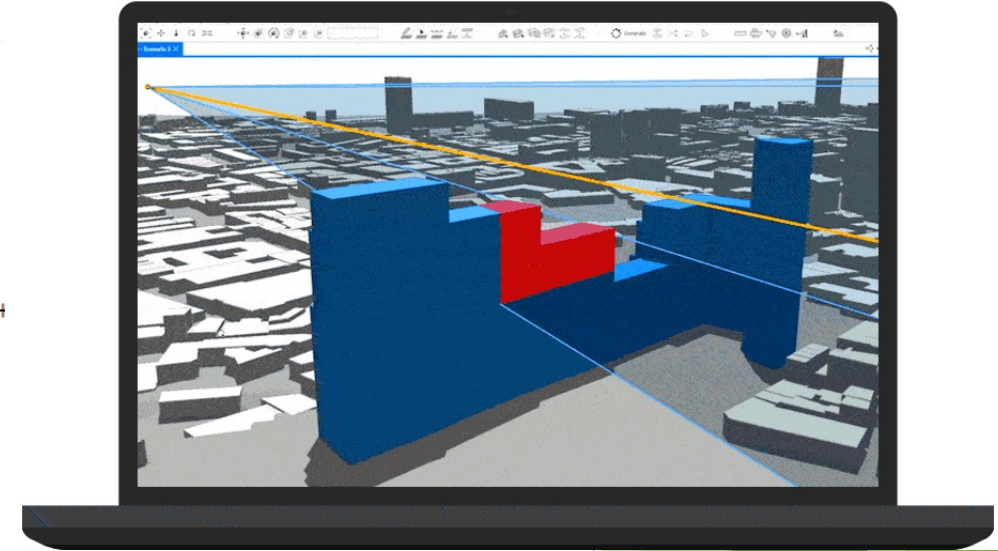
WAGmob • [Books & reference](#) > [Reference](#)

★★★★★ WAGmob: Over One million Paying Customers from 175+  
★

[More](#)



PEGI 3



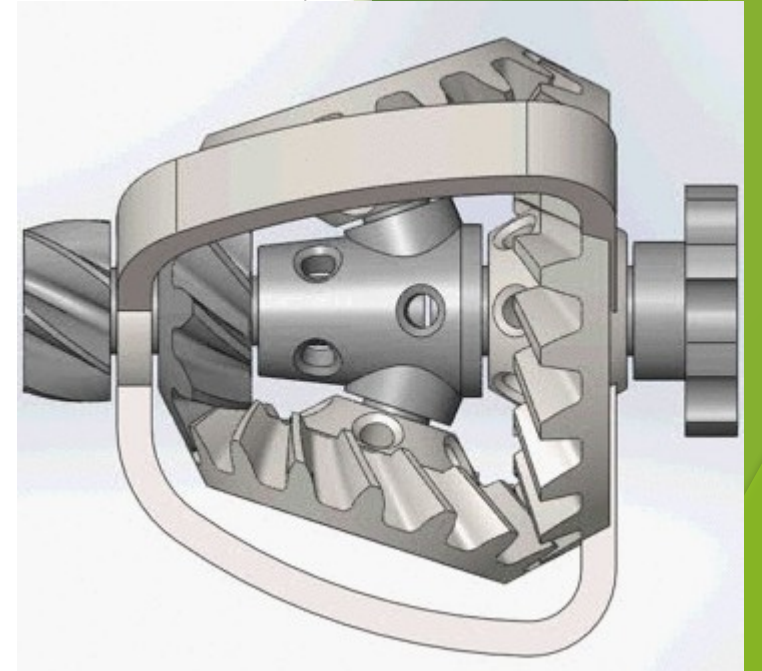
- ▶ WAGmob brings you, Simple and Easy, on-the-go learning app for "Civil Engineering". The app helps you to understand the basics of "Civil Engineering".

How to develop such applications  
without understanding of  
mathematics?

# Math in CS

## Mechanical Engineering apps

- ▶ Some applications for 3D designing in the field of Mechanical Engineering
  - ▶ AUTODESK
  - ▶ INVENTOR
  - ▶ Etc.
- ▶ All these application needs heavy math at back end.
- ▶ As in given figure there are Force, Rotation, Momentum and Velocity involved.
- ▶ By changing one quantity effects other quantities and the changes can be measured/observed through computer



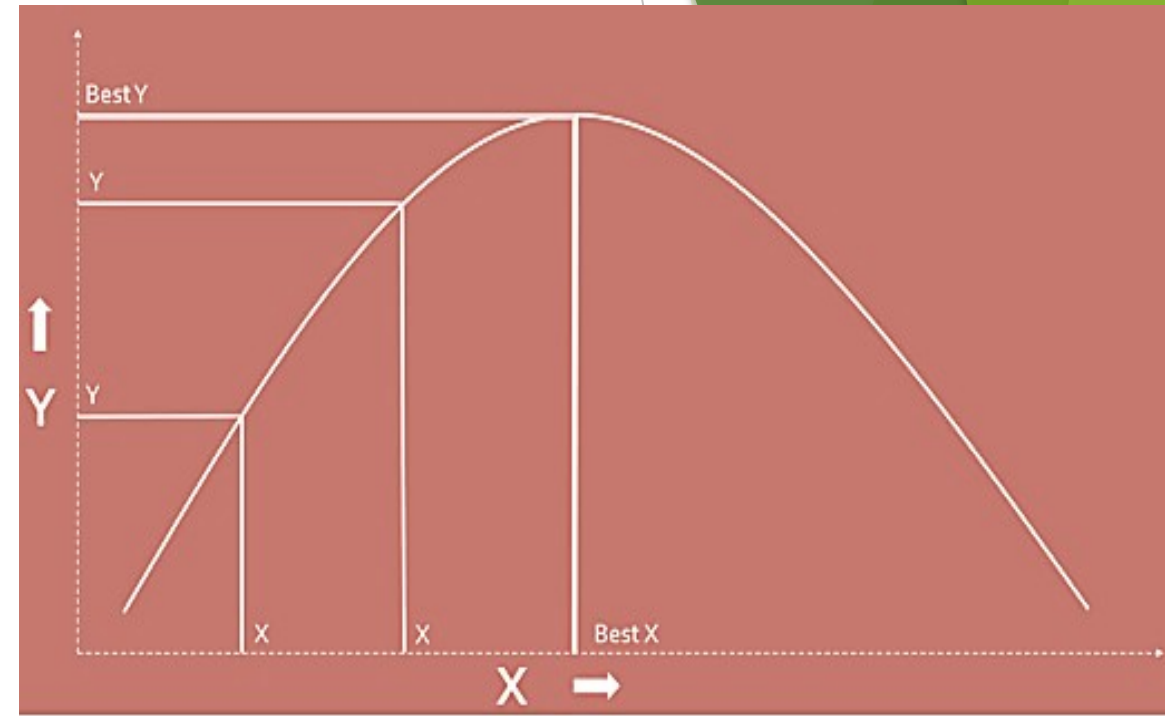
# Concept of Optimization

- ▶ In mathematical terms, an ***optimization problem*** is the problem of finding the *best* solution from among the set of all *feasible* solutions.
- ▶ In simple terms optimization is choosing **INPUTS** that will result in the best possible **OUTPUTS**



# Optimization

- ▶ Let's take a look at a very simple example of an optimization problem:
- ▶ Given a parabola, choose  $x$  to get the **largest  $y$** . We can try different  $x$  values to see the resulting  $y$  value.
- ▶ Eventually we can find the **maximum  $y$**  value by choosing **Best  $X$** .
- ▶ You may also have solved this type of problem in calculus class by taking the derivative of the parabola and setting it equal to zero.



Where can we use OPTIMIZATION?



# Bridge Construction

Inputs



Outputs

- ▶ Designing a bridge that can carry the maximum load possible for a given cost.
- ▶ Input is Design and output is to Maximize Load Bearing



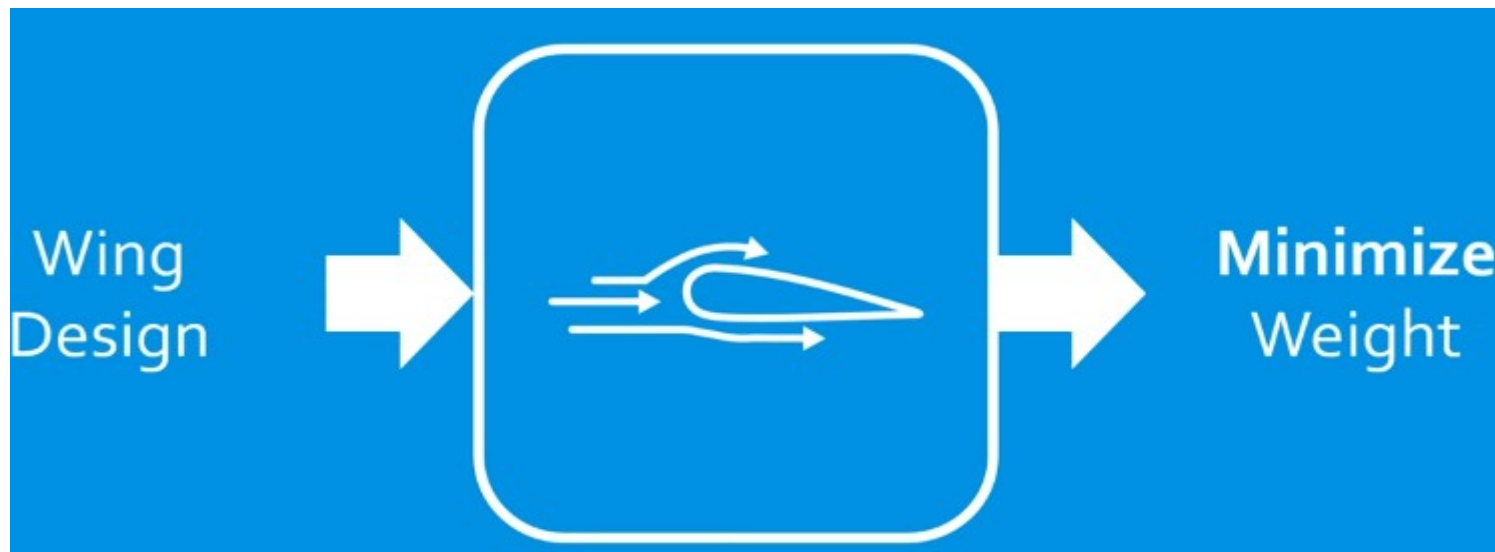
# Airplane Wing Design

Inputs



Outputs

- ▶ Design an airplane wing to minimize weight while maintaining strength.
- ▶ Input is Wing Design and output is to Minimize Weight



# Stock Market

Inputs



Outputs

- ▶ Selecting the best set of stocks to invest in to maximize returns based on predicted performance.
- ▶ Input is Stock Portfolio and Output is to maximize returns on investment



# Warehouse placement

Inputs



Outputs

- Choosing the optimal location for a warehouse to minimize shipment times to potential customers.



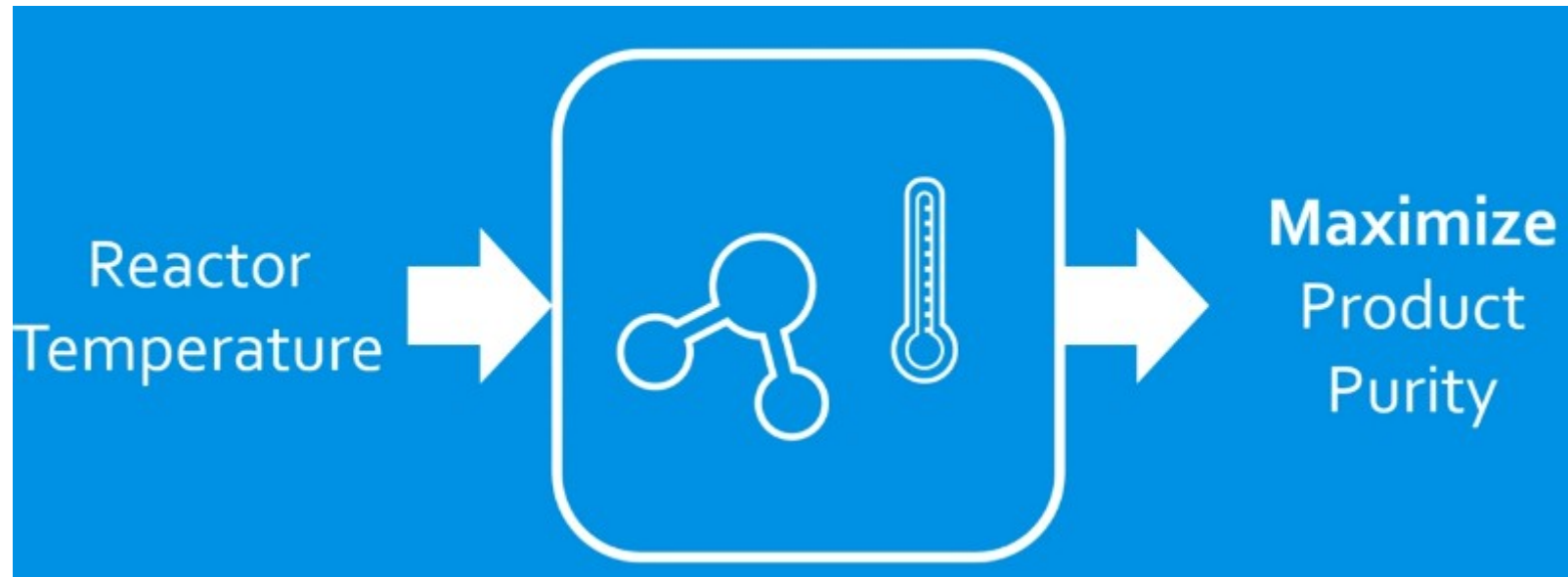
# Temperature control of a chemical reaction

Inputs



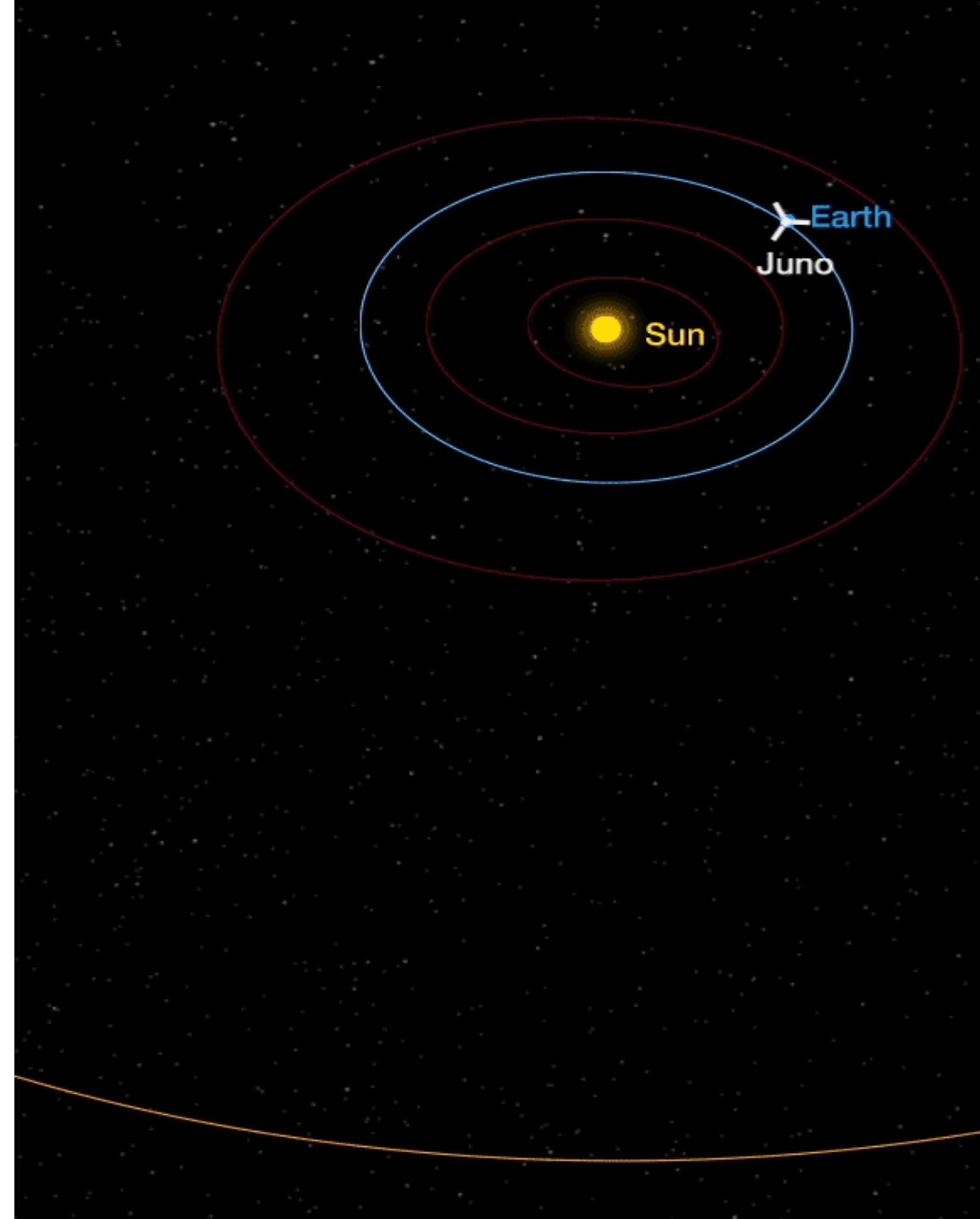
Outputs

- ▶ Controlling the temperature of a chemical reaction throughout a process to maximize the purity of a desired product.



# Space Shuttle / Suborbital Vehicle trajectory optimization

- ▶ Even optimization is involved in life critical missions
- ▶ Trajectory of space shuttle is calculated and optimized to its target position by minimizing fuel cost and time.



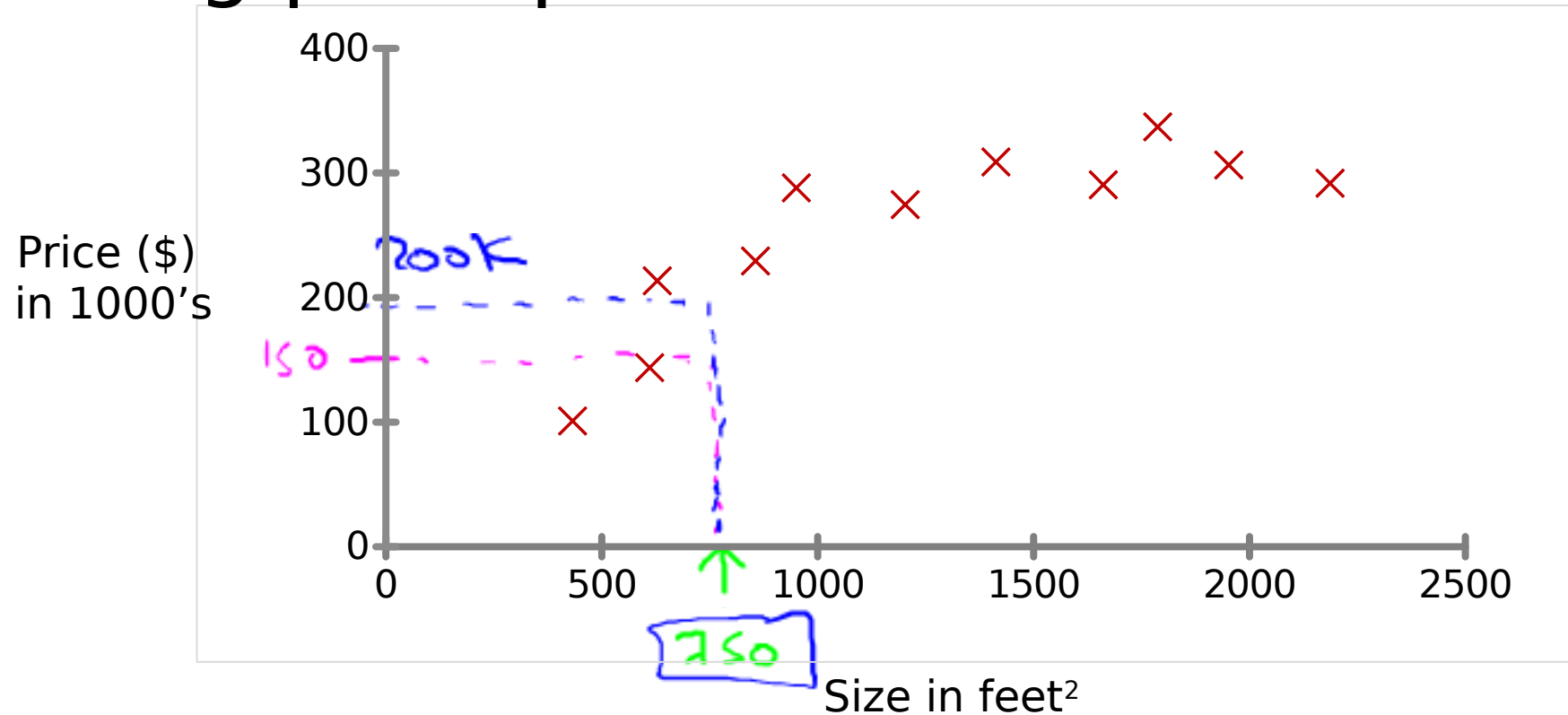


# Optimization

Continue...

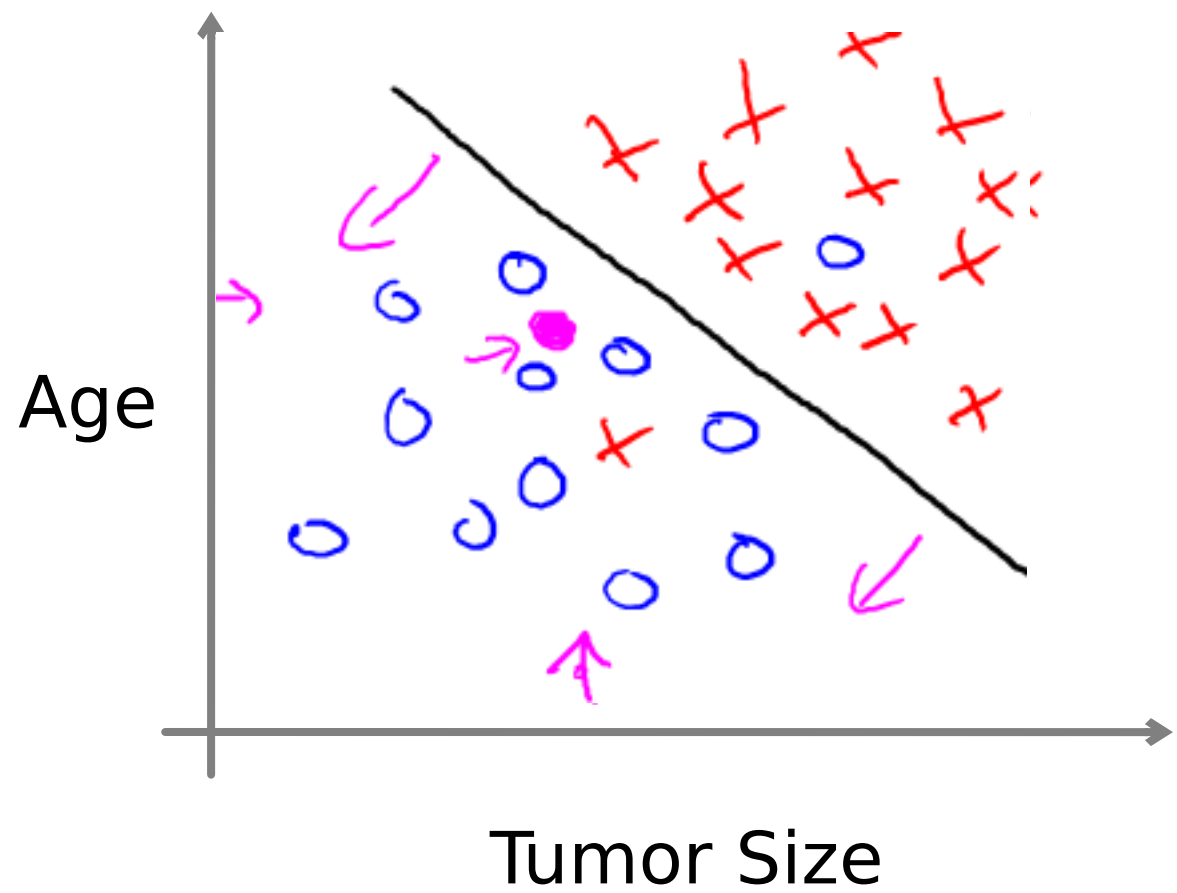
- ▶ As you can see, optimization is a powerful tool in many applications.
- ▶ This is just a small sampling of the many fields that make use of optimization techniques to improve the quality of their solutions.
- ▶ If something can be modeled mathematically, it can usually be optimized.

# Housing price prediction.



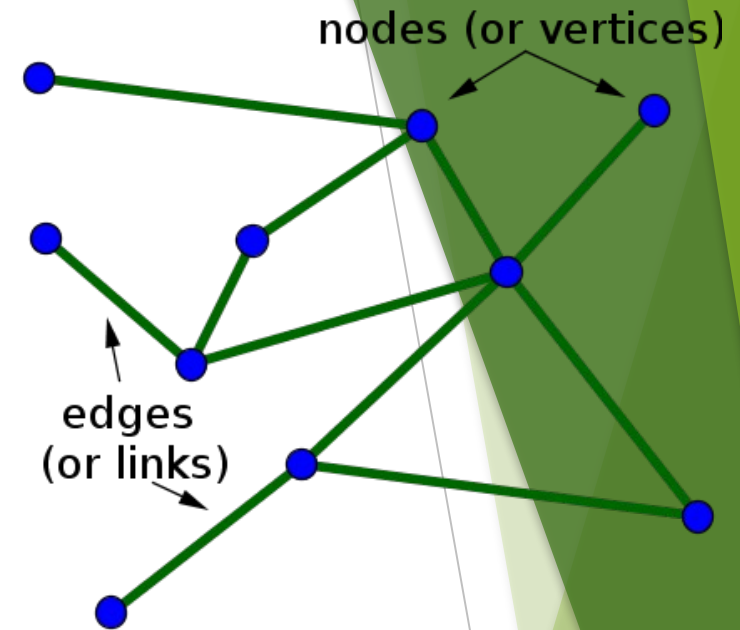
Supervised Learning  
“right answers” given

Regression: Predict  
continuous valued  
output (price)



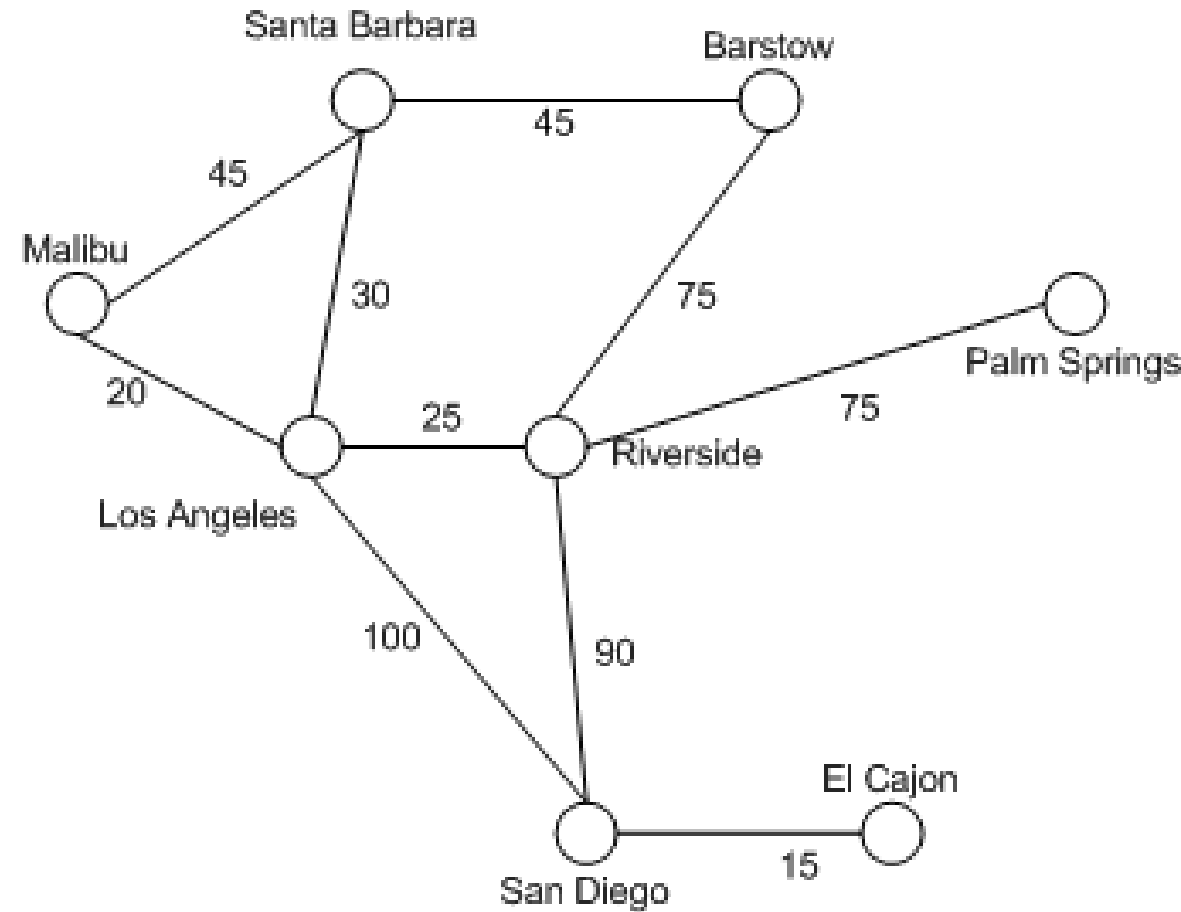
# Introduction to Graph

- ▶ In Computer Science, graph is a collection of connected **NODES** (vertices) with the help of **EDGES** (links)
- ▶ A **node** is a thing or an entity and we can assign some value to it, so a person, a car and a city are examples of a node.
- ▶ An **edge** can be define as a relation of some sort between two or more nodes
- ▶ A perfect layman's example might be **Facebook**.
- ▶ The network of you, your friends, and their friends etc. are collectively referred to as the **social graph**
- ▶ Here people are nodes connected through friendship edges



# Graph

- ▶ Similarly we can show connected cities using graph as in given figure
- ▶ Cities are represented as nodes (vertices) and the road's distance is represented on edges.



# Working with Graphs



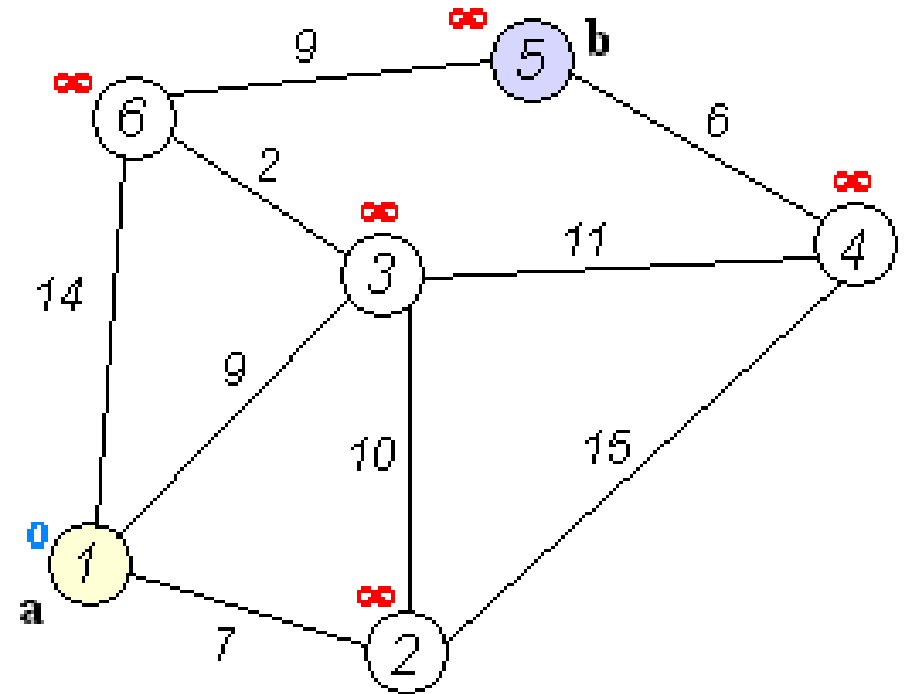
# Point to Ponder

- ▶ Do you know:
  - ▶ How does facebook suggest friends?



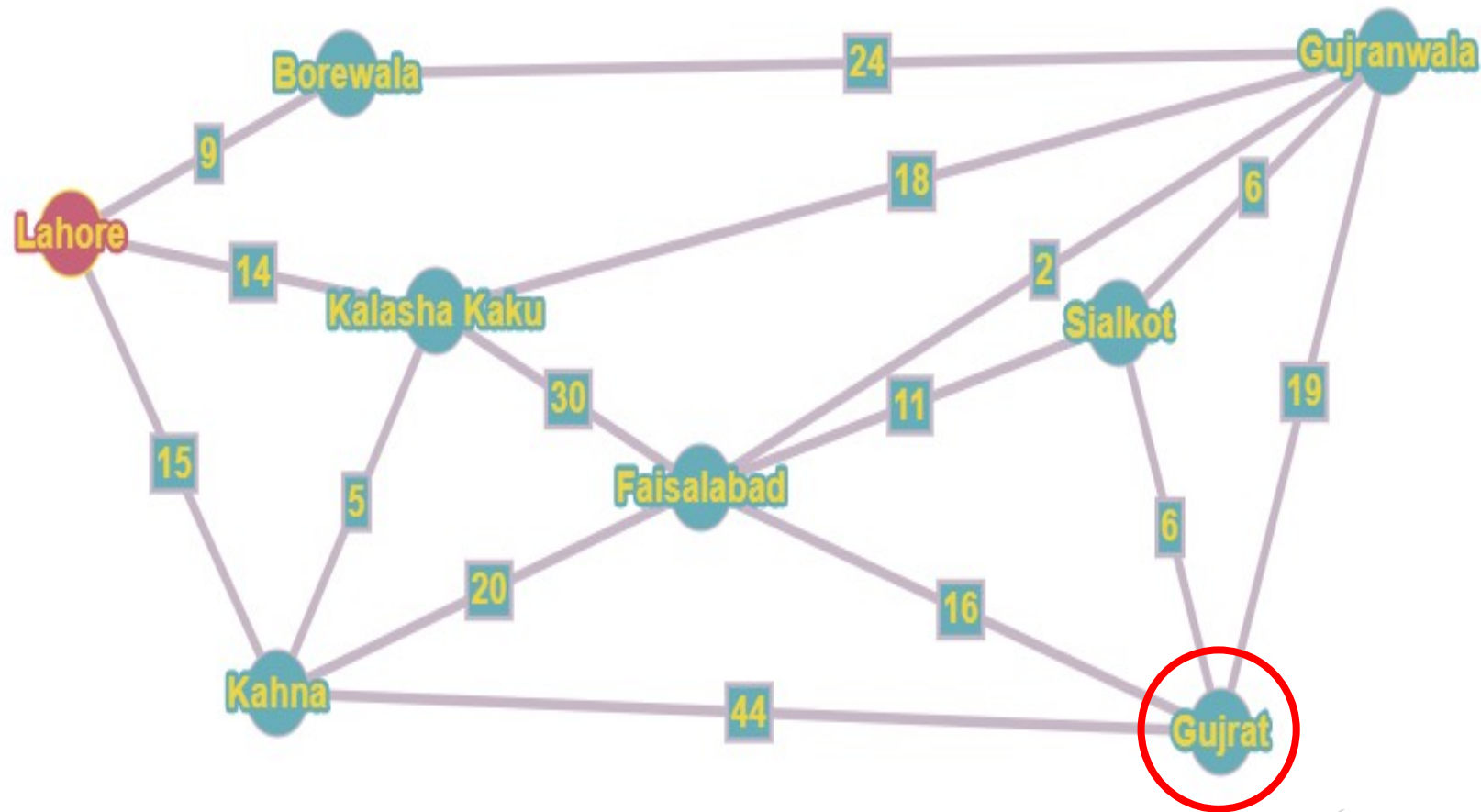
# Finding shortest path between two nodes

- Finding shortest path
- Can you find the shortest path between node 1 and 5 in given graph?



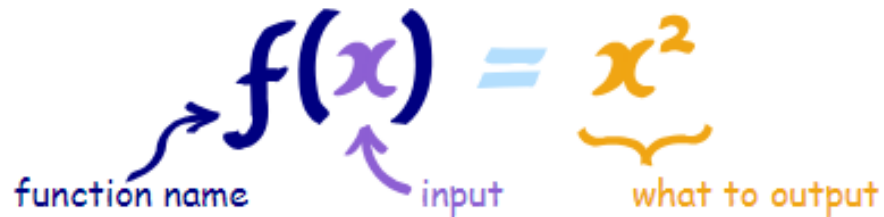
# Activity

- Can you find the shortest path from Lahore to Gujrat?



# Functions

- ▶ A function relates an input to an output.
- ▶ It is like a machine that has an input and an output. And the output is related somehow to the input
- ▶ Representation of a function



The diagram shows the equation  $f(x) = x^2$ . The 'f' is in dark blue, the '(x)' is in purple, and the '=' is in light blue. The 'x' is in purple, and the '2' is in orange. A curved arrow points from the text 'function name' to the 'f'. A straight arrow points from the text 'input' to the 'x'. A bracket under the 'x^2' is labeled 'what to output'.

We say "f of x equals x squared"

# A function *relates* an input to an output. How?



Example: this tree grows 20 cm every year, so the height of the tree is *related* to its age using the function  $h$ :

$$h(\text{age}) = \text{age} \times 20$$

So, if the age is 10 years, the height is:

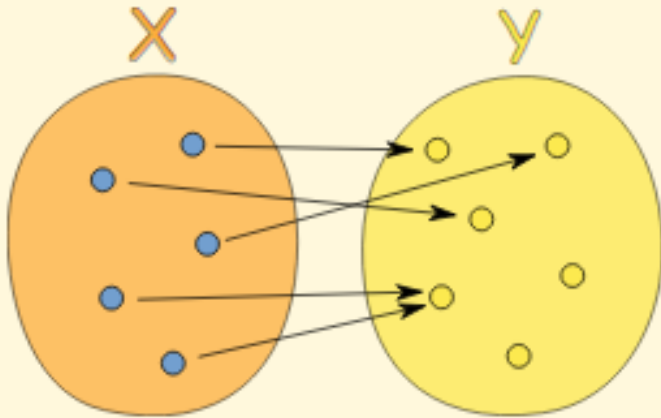
$$h(10) = 10 \times 20 = 200 \text{ cm}$$

Here are some example values:

age	$h(\text{age}) = \text{age} \times 20$
0	0
1	20
3.2	64
15	300
...	...

# A function has a special rule

1. It must work for **every** possible input value
2. And it has only **one relationship** for each input value



## Formal Definition of a Function

A function relates **each element** of a set with **exactly one** element of another set (possibly the same set).



End of Lecture 04

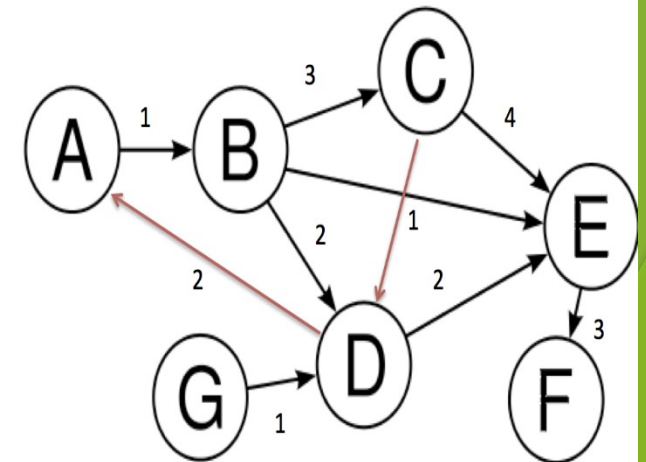
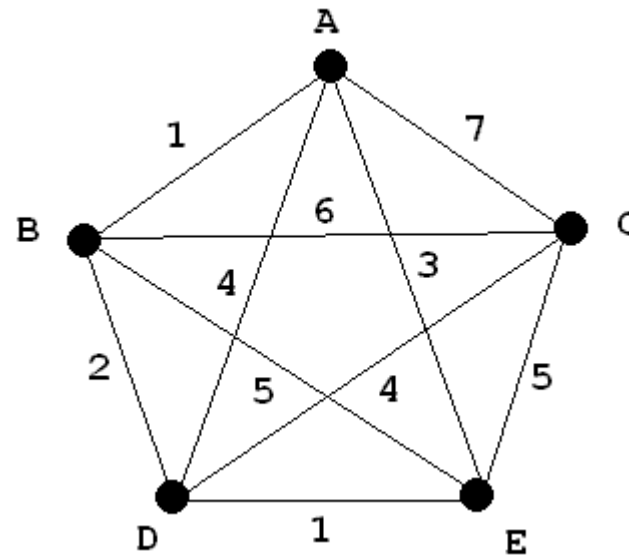
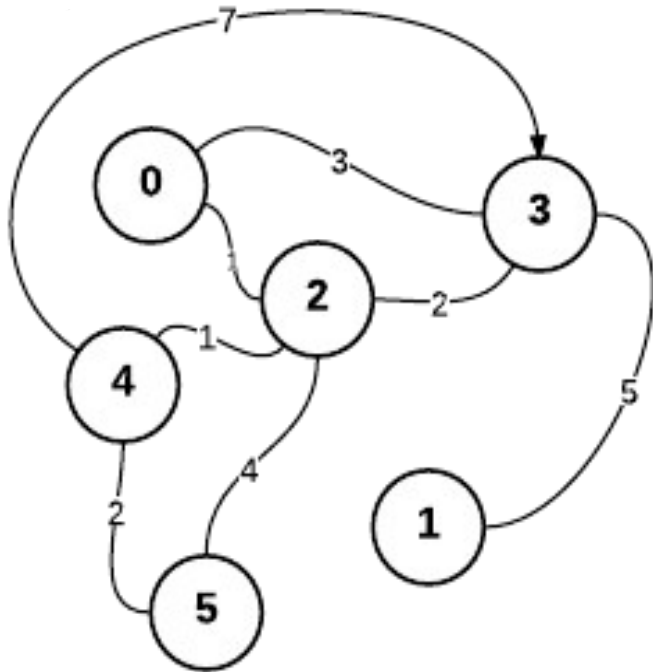
# Activity-01

► Can you decipher (Decode) the following messages?

1. YTIVITCA TSRIF SI SIHT STNEDUTS OLLEH [Hint: reverse string](#)
2. XLI JMVWX IBEQTPI AEW IEWC  
[\(Key is 4 and rotated rightward\)](#)

## Activity-02

Represent the following graph in form of adjacency matrix



## Activity-03

Draw graph from each of the following adjacency matrices

$$\begin{matrix} & a & b & c & d \\ \begin{matrix} a \\ b \\ c \\ d \end{matrix} & \begin{pmatrix} 0 & 3 & 0 & 2 \\ 3 & 0 & 0 & 1 \\ 0 & 0 & 1 & 2 \\ 2 & 1 & 2 & 0 \end{pmatrix} \end{matrix}$$

	①	②	③	④	⑤	⑥
①	0	1	1	0	0	0
②	-1	0	0	1	0	0
③	-1	0	0	1	0	0
④	0	-1	-1	0	1	0
⑤	0	0	0	-1	0	1
⑥	0	0	0	0	-1	0

	A	B	C	D	E	F	G
A	0	0	1	1	0	1	0
B	0	0	0	1	1	0	0
C	1	0	0	0	0	1	0
D	1	1	0	0	0	1	0
E	0	1	0	1	0	0	0
F	1	0	1	1	0	0	0
G	0	0	0	0	0	0	0

7

7

# Activity-04

Can you find the sho

