

80% chance of rain in Oxford

+0.11.2.26

less effective

engaging is better



ink + think



taught in school

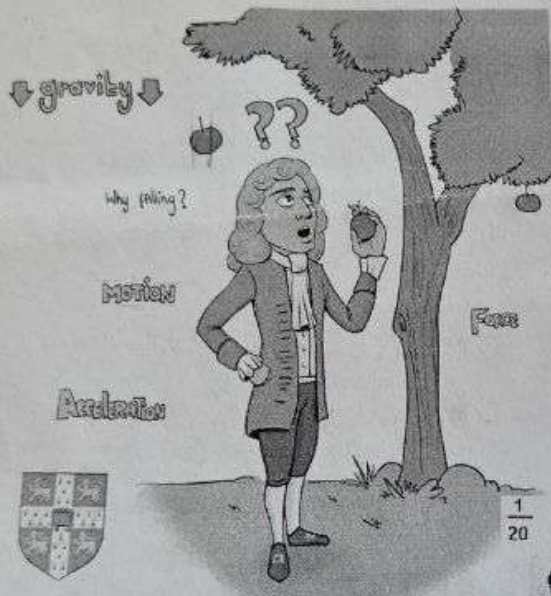
shifts from intuitive

Complex equations and formal repr.

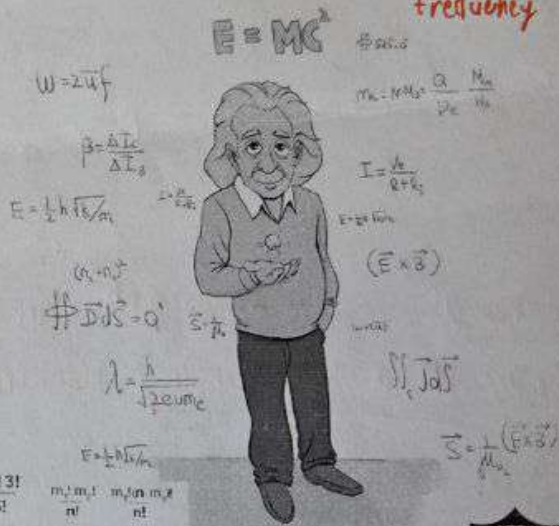
School  $\rightarrow$  gravity  $\rightarrow$  Motion

==formalism==> University

### CONCRETE AND ABSTRACT THINKING



ISAAC NEWTON



ALBERT EINSTEIN

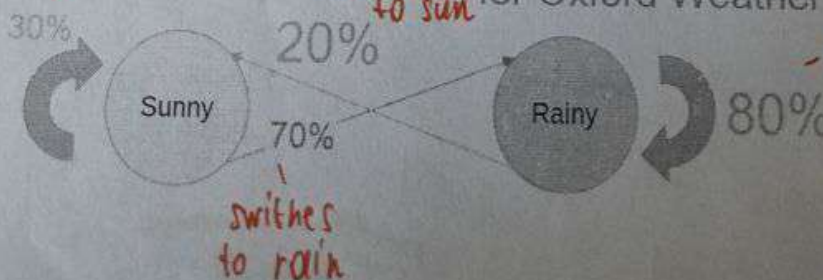
Motivation: 80% chance of rain  
Let  $A_i$  be the event of rain on day  $i$  of the term,  $i \in \{1, \dots, n\}$

Suppose the events  $A_i$  are independent.

Oxford	Tue 13th	Wed 14th	Thu 15th	Fri 16th
	10° 9°	13° 10°	13° 8°	11° 7°
	70%	70%	70%	70%

### Markoff Chain Probability Model

stay sunny



switches to sun

switches to rain

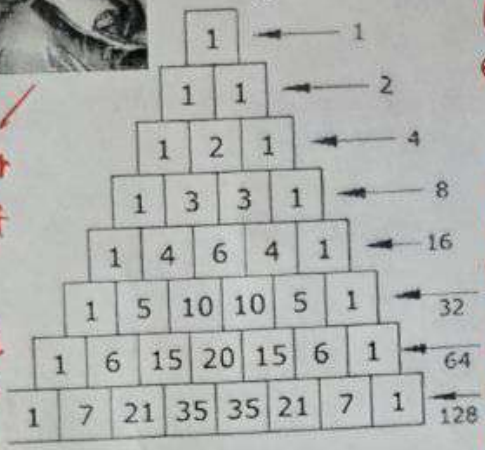
prob of next state depends on current stage

stays at rain

tree diagram



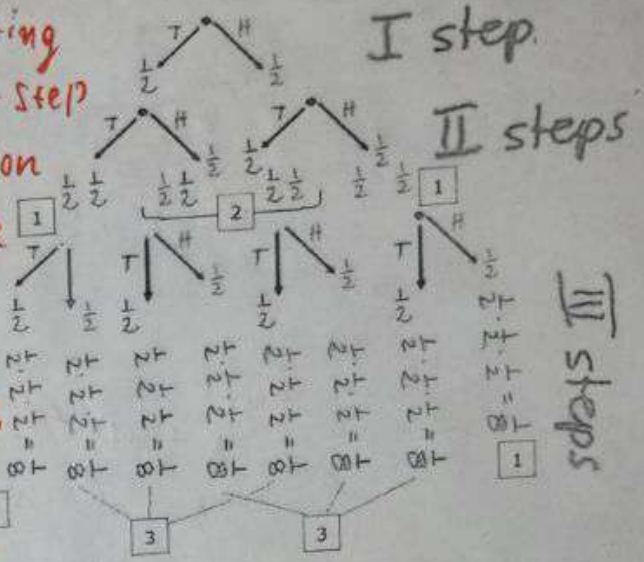
Pascal's triangle



triangular array of numbers where each number is the sum of two above it

illustrating step-by-step construction of triangle

splits into 2 branches, summing values from previous step



$(a + b)^0 =$   
 $(a + b)^1 =$   
 $(a + b)^2 =$   
 $(a + b)^3 =$   
 $(a + b)^4 =$   
 $(a + b)^5 =$

1  
 $a + b$   
 $a^2 + 2ab + b^2$   
 $a^3 + 3a^2b + 3ab^2 + b^3$   
 $a^4 + 4a^3b + 6a^2b^2 + 4ab^3 + b^4$   
 $a^5 + 5a^4b + 10a^3b^2 + 10a^2b^3 + 5ab^4 + b^5$

Newton's Binomial

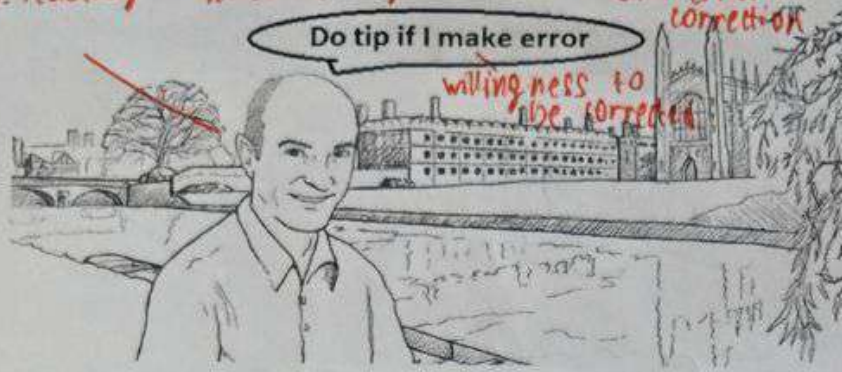


Binomial theorem -  $(a+b)^n$  can be expanded using the coefficients from Pascal's triangle. General term in the expansion is given by  $\binom{n}{k} a^{n-k} b^k$ , where  $\frac{n}{k}$  is binomial coefficient

+0.1 +0.1 +0.1 +0.1 +0.1

Thorn

Sir Dr. D. MacKay - notable figure in IT and error correction



Sir Dr. D. MacKay,  
University of Cambridge  
(22 April 1967 – 14 April 2016)

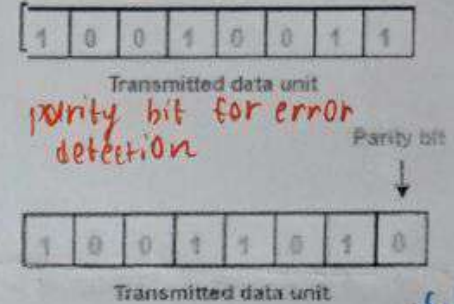


don't commit to both fields

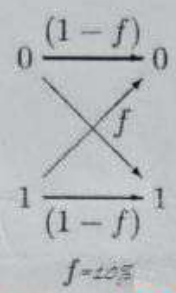
"I believe in clean energy, but I also believe in mathematics"



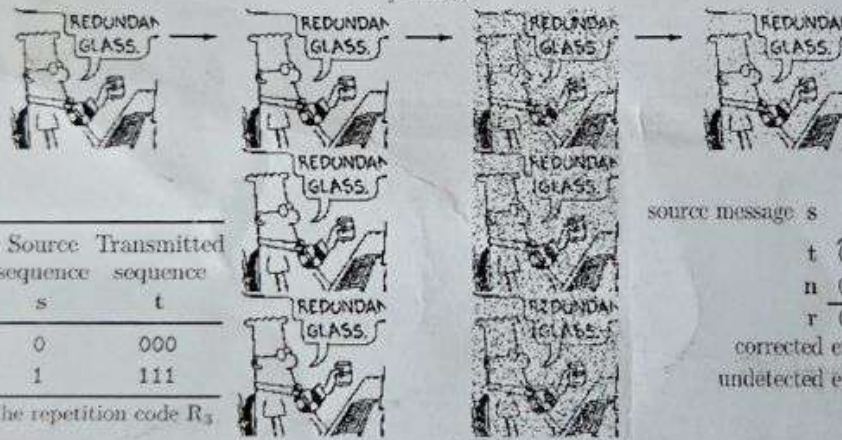
Machine translation artificial coding intelligence Cryptography



Redundant data helps ensure accuracy and reliability in the presence of errors



original data s ENCODER t each bit repeated reception r DECODER s



Source sequence	Transmitted sequence
s	t
0	000
1	111

source message	s	0	0	1	0	1	1	0
t	000	000	111	000	111	111	000	
n	000	001	000	000	101	000	000	
r	000	001	111	000	010	111	000	
corrected errors	*							
undetected errors								

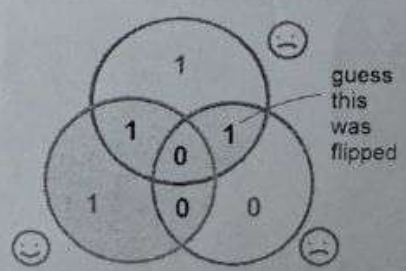
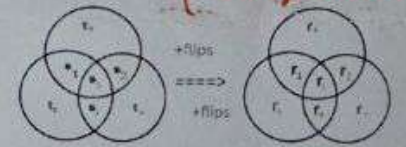
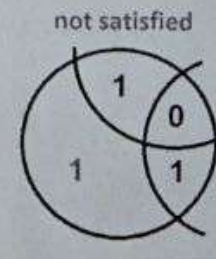
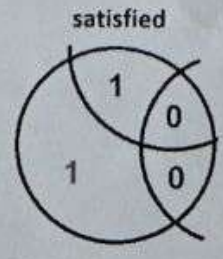
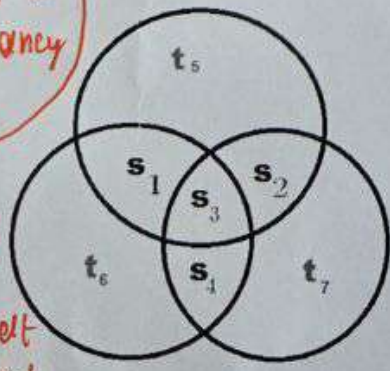
$$P(x) = \frac{n!}{(n-x)! x!} p^x f^{n-x}$$

repeat each bit multiple times to create redundancy

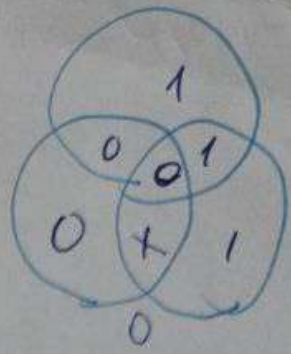
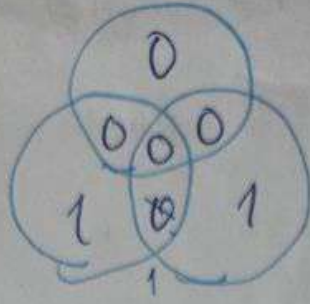
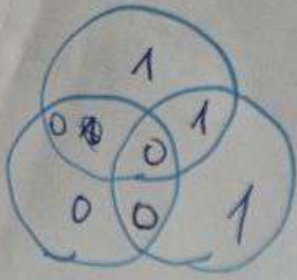
### 7.4. Hamming code.

$$\frac{4}{\Sigma} \rightarrow \frac{7}{t}$$

type of binary used for error correction that can detect and correct single-bit errors



+0.1



a private land-grant research un.  
in Cambridge, established in 1861  
Technology and science



Massachusetts Institute of Technology (MIT)

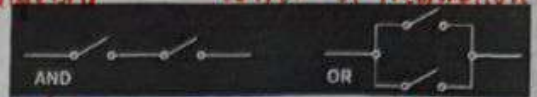
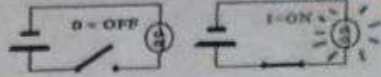


Lecture by Pr. Bob Gallagher  
Boole (1815-1864) & Shannon (1916-2001)



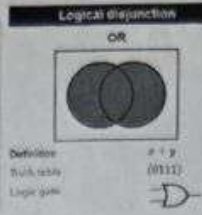
Boolean algebra

father of information theory

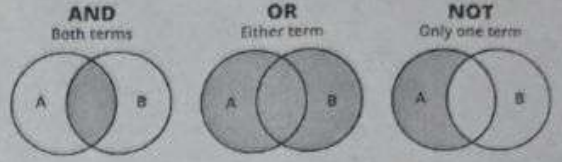


Logical addition  
(disjunction)

A	B	$A \vee B$
True	True	True
True	False	True
False	True	True
False	False	False

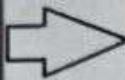


both closed  
BOOLEAN LOGIC  
at least one



A - and  
V - or  
T - not

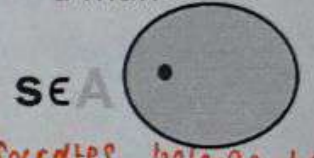
Good logic



Socrates was a philosopher

philosophers are men

Socrates was a man



Socrates belongs to the set of philosophers (Phi)

philosophers are a subset of men (A)

Socrates belongs to the set of men

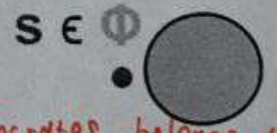
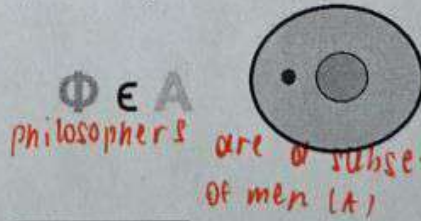
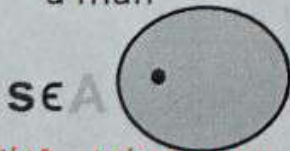
Bad logic



Socrates was a man

philosophers are men

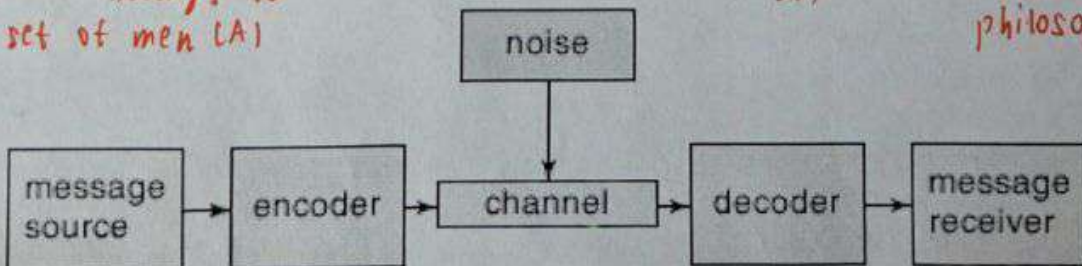
Socrates was a philosopher



Socrates belongs to the set of men (A)

philosophers are a subset of men (A)

Socrates belongs to philosophers



# Resume of Lecture by Pr. Bob Gallager from MIT Massachusetts Institute of Technology (MIT)

George Boole (1815-1864) developed Boolean logic.

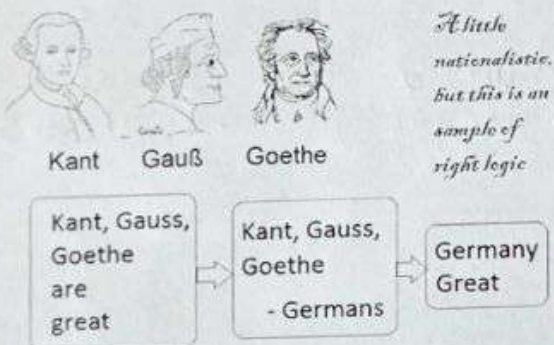
The principles of logical thinking have been understood (and occasionally used) since the Hellenic era.

Boole's contribution was to show how to systemize these principles and express them in equations (called Boolean logic or Boolean algebra).

Claude Shannon (1916-2001) showed how to use Boolean algebra as the basis for switching technology. This contribution systemized logical thinking for computer and communication systems, both for the design and programming of the systems and their applications.

Logic continues to be abused in politics, religion, and most non-scientific areas.

Logic continues to be abused in politics, religion and most non-scientific areas



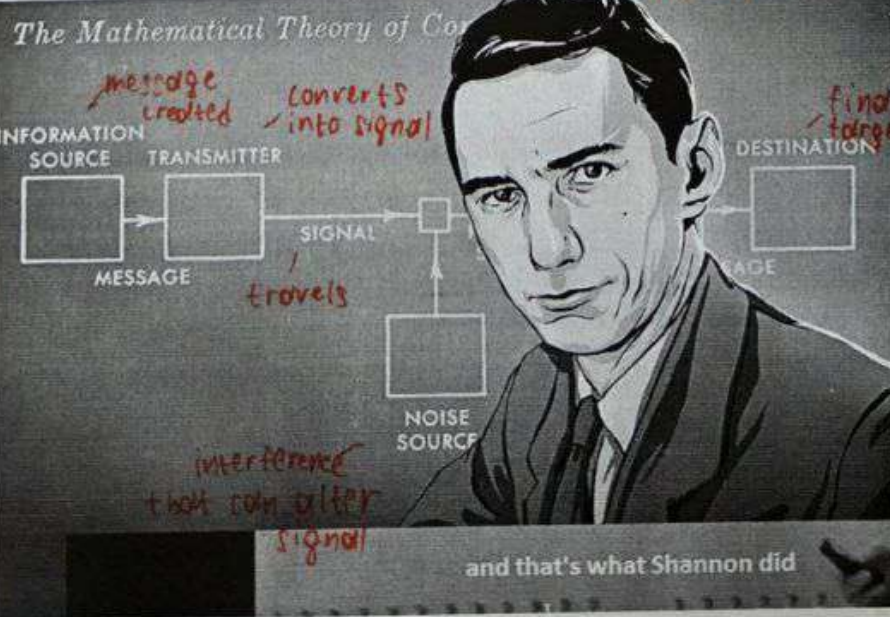
Valid structure

A little nationalistic. But this is an example of right logic



Bad logic (abuse of logic)

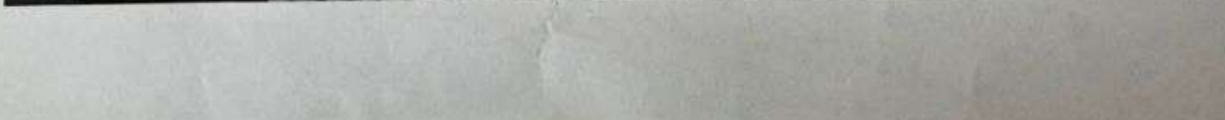
Invalid structure (generalizes personal attributes based on group identity)



Creating a reliable connection over an unreliable (noisy) channel that's what IT is about

diagram of a communication system

and that's what Shannon did



This is the program we need to write today

```
class ABBA
{
    static void Main(string[] args)
        // Here's a method called Main.
    {
        System.Console.WriteLine("ABBA!");
    }
}
```

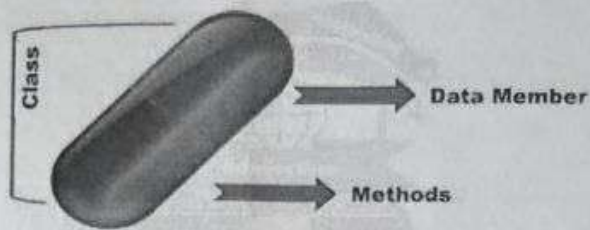


So there's the keyword class. Unlike C++, in C# all code must be placed in a class.

Encapsulated in a class.



Medicines Inside Capsule



A ≠ a

C# is case sensitive

C:\WINDOWS\Microsoft.NET\Framework\v3.5\ csc.exe

(C:) > Windows > Microsoft.NET > Framework > v3.5 >

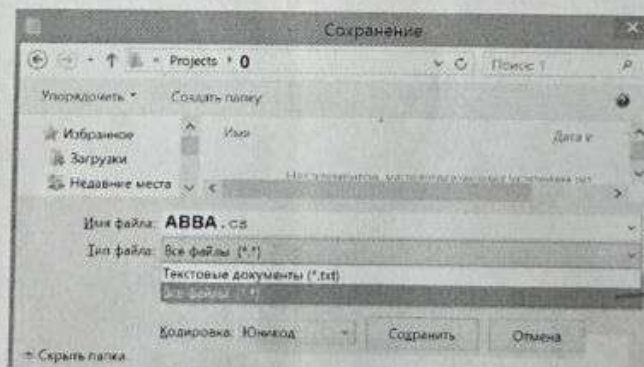
Имя	Дата изменения	
AddInUtil.exe	03.08.2013 8:40	
AddInUtil.exe.config	18.06.2013 16:24	ABBA.cs => csc.exe = ABBA.exe
csc.exe	03.08.2013 8:40	C# Compiler

**Step 1.** And on my HDD, I also make a folder with the same name D:\IT

**Step 2.** In the folder E:\IT\ we make the folder of the **Projects** - E:\IT\Projects

And in the **Project** folder make folder **0** - E:\IT\Projects\0\ where our today's practical work will be stored

**Step 3.** As I mentioned above, C# is a built-in language of Windows. Notepad is enough to write a program



You need to switch from \*.txt (Text documents) to \*.\* (all files)

Otherwise, notepad with \*.txt extension

**Step 4.** Entering command mode

Start=>Run=>cmd

cd E: - After that go to the folder IT/Projects/0/  
cd IT - Then go to the folder Projects  
cd projects - Then go to the folder 0  
cd 0 -

```
E:\>cd IT
E:\IT>cd Projects
E:\IT\Projects>cd 0
E:\IT\Projects\0>
```

Step 5.

Now we need to compile the file using the compiler csc.exe which is in the folder C:\Windows\Microsoft.NET\Framework\v3.5

C:\WINDOWS\Microsoft.NET\Framework\v3.5\csc.exe ABBA.cs

the result is a file ABBA.exe that can already be run (which is located in the same folder). If you have taken the 1st step, then this means that the education-process has begun. This is victory. csc /target:library ABBA.cs - will make ABBA.dll.



Step 6. Modify the file as follows using System;

```
class ABBA
{
    static int Factorial(int n)
    {
        if (n == 1) return 1;
        return n * Factorial(n - 1);
    }
}
```

```
static void Main(string[] args)
// Here's a method called main.
{
    System.Console.WriteLine("ABBA -"+
        Factorial(4));
}
}
```

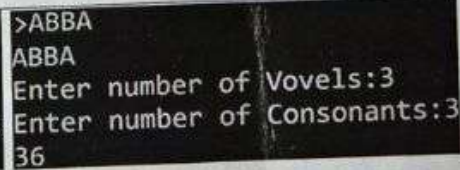
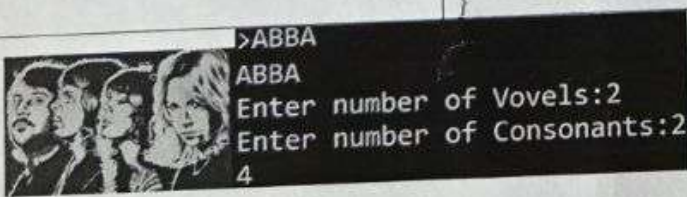
```
>C:\WINDOWS\Microsoft.NET\Framework\v3.5\csc.exe ABBA.cs
>ABBA
ABBA - 24
```

Step 7. Modify the file as follows

using System;

```
class ABBA
{
    static int Factorial(int n)
    {
        if (n == 1) return 1;
        return n * Factorial(n - 1);
    }
}
```

```
public static void Main()
{
    System.Console.WriteLine("ABBA");
    System.Console.Write("Enter number of Vowels:");
    string s = Console.ReadLine();
    int vowels=int.Parse(s);
    System.Console.Write("Enter number of Consonants:");
    s=System.Console.ReadLine();
    int consonants=int.Parse(s);
    Console.WriteLine(Factorial(vowels)*Factorial(consonants) );
}
}
```



# +0.1 Entropy



Say NO to the first



Say YES to the second if it is better than the first



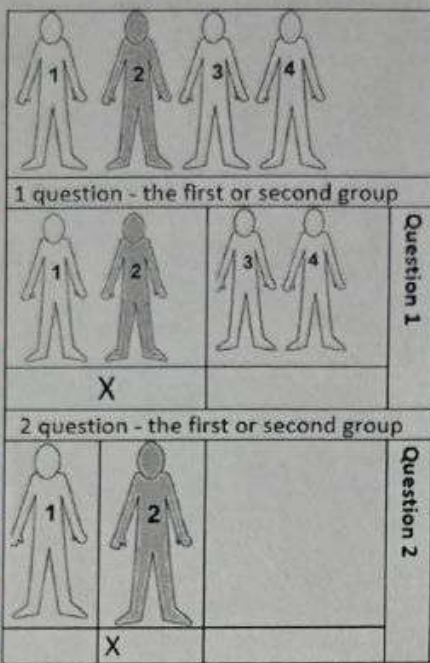
Say NO to the third only if it is worse than all the others

determining average number of questions needed to identify specific person from a set of candidates based on prob.

$1 \cdot 0.5 +$	$2 \cdot 0.25 +$	$3 \cdot 0.125 +$	$3 \cdot 0.125$

$\log_2 2$   
 $\log_2 \frac{1}{2}$

comparing candidates in pairs to determine the best option



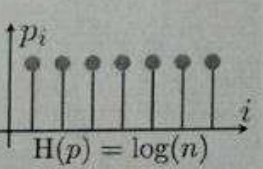
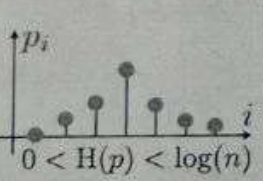
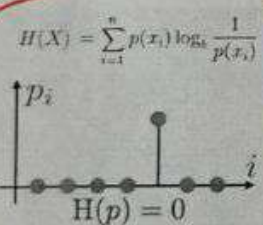
Question 1. Is this Zuckerberg?	50%	$1 \cdot 0.5 \frac{1}{2}$
Question 2. Is this Sergey Brin?	25%	$2 \cdot 0.25$
Question 3. Is this Stefan from BMW?	12.5%	$3 \cdot 0.125$
So Prince Saud	12.5%	$3 \cdot 0.125$
Average number of questions = 1,75		

Shannon entropy

0.5 0.0000 1.0.5  
2.5 0.0000 ← 2.0.25  
3.75 0.0000 ← 3.0.125  
3.75 0.0000 ← 3.0.125  
1.75

Average number of questions =  $2 \cdot 0.25 + 2 \cdot 0.25 + 2 \cdot 0.25 + 2 \cdot 0.25 = 2$

calculates the entropy  
size, measurement of uncertainty or information content



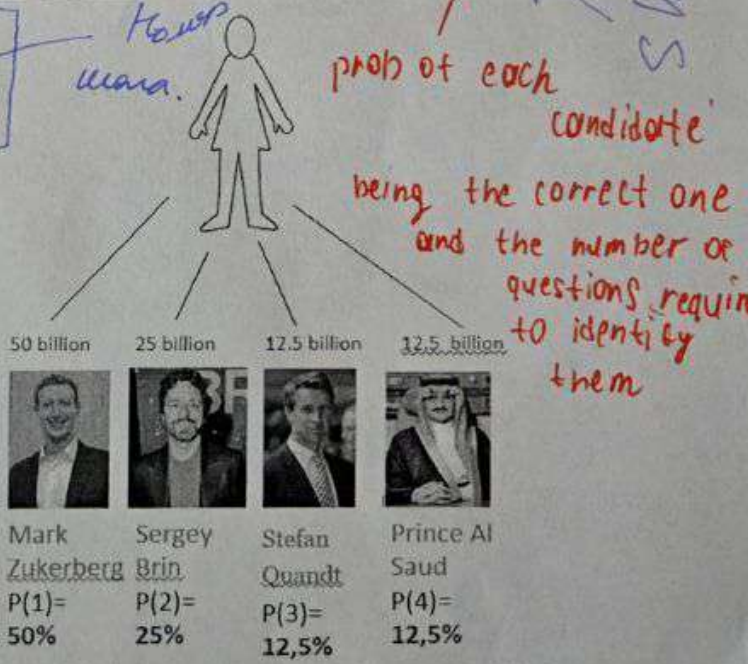
$$\sum_{i=1}^n p(i) \log_2 \frac{1}{p(i)}$$

Quantifying information

$$I(x_i) = \log_2 \left( \frac{1}{p_i} \right)$$

number of bits required to encode choice

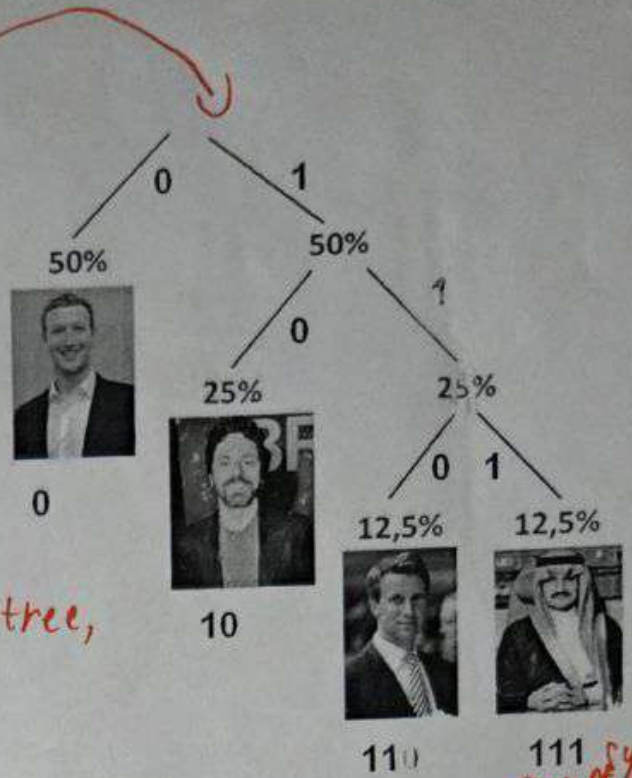
$$\sum_{i=1}^n p(x_i) I(x_i)$$



1 (50%) VS Kp Kp  
2 (25%) - + +  
3 (25%) Kp Kp Kp

+0,1

Huffman tree - process of creating a Huffman coding tree. Each character assigned a binary code based on its frequencies. Characters with higher frequencies are closer to the root, resulting in shorter codes. The binary codes are created by traversing the tree, left branches are 0, the right are 1.



1. each symbol is independent of the others, meaning prob of symbol don't depend on others

First-order approximation (symbols independent but with frequencies of Belarusian txt).

Мама мыла ра		
М - 3	— 30%	1-3 М
а - 4	— 40%	4-7 а
ы - 1	— 10%	8 -ы
л - 1	— 10%	9 -л
р - 1	— 10%	10 -р
10		
лла <span style="border: 1px solid black; padding: 2px;">мам</span> ра		

Мама мыла ра		
Ма - 2	22%	1-2 М
ам - 2	22%	3-4 а
мы - 1	11%	5 М
ыл - 1	11%	6 ы
ла - 1	11%	7 л
ар - 1	11%	8 а
ра - 1	11%	9 р
9		

breaks down the sentence into ind. symbols using 1-order



numbers represent position in text

0. 4 6 7 3 1 9 1 6

ам ыл ла ам ма ра ма ыл

мылла рама

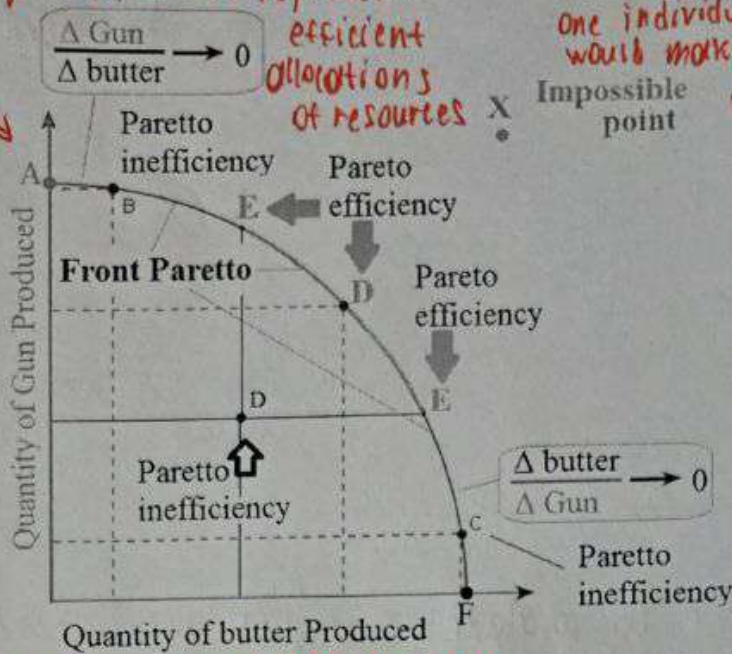


Second-order approximation (diagram 2 symbols structure as in Belarusian)

prob. of symbol depends on previ

5-order

trade off between two goods. Points represent efficient allocations of resources



Pareto efficiency - state where resources are allocated in the most efficient manner, such that any change to make one individual better off would make another worse off



by Vilfredo Pareto 1848-1923

The orange sector E-D-E is the most Pareto efficient - since an increase in one indicator leads to a decrease in another.

example of game theory where two ind. might not cooperate

Prisoners' dilemma

		prisoner B	
		confess	remain silent
prisoner A	confess	5 years, 5 years	0 year, 20 years
	remain silent	20 years, 0 year	1 year, 1 year

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each mafioso has 2 choices

1) if both remain silent they're considered 'man of respect', leading to a lesser punishment

2) if one confesses and other doesn't, the one who did - 'Penito'

## Game Theory Nash Equilibrium



\*\* => Nash equilibrium

		Player 2	
		Recognition;	Non-recognition;
Player 1	Recognition;	1, -5	2, -20
	Non-recognition;	-20, 0	-1, -1

-1-1  
Pareto Optimality

Nash Equilibrium - concept of game theory, where no player can benefit by changing their strategy while the other keeps their unchanged

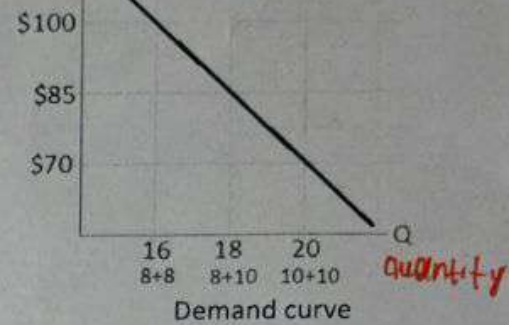
Historical price of oil from 2000 to 2021 highlights significant fluctuations, including a peak around 2008

**Oil price hits 18-year low**



















Brent crude, US dollars per barrel



As the quantity demanded increases, the price decreases, following the law of demand



Game theory, used to analyze strategies and outcomes

Barrel 		1.	2.
		$8 \cdot 10^6$  day	$10 \cdot 10^6$  day
1. 	$8 \cdot 10^6$ 	 $\$800$ millions per day  $\$100$  $\$800$ millions per day	 $\$850$ millions per day  $\$85$  $\$680$
	$10 \cdot 10^6$ 	 $\$680$ millions per day  $\$85$  $\$850$ millions per day	 $\$700$ millions per day  $\$70$  $\$700$ millions per day

two players and their strategies



- Optimal both cooperate, leading to maximizing their joint revenue ( $1600m$  per day)
- one increases production to  $10m$ , other  $-3m$  total revenue decreases, player producing more oil gains larger share
- both increase production to  $10m$ , reduces revenue for both

John Nash, American mathematician, earned Nobel prize in Economic Sciences in 1994