Архипкова Анастасия 354

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

Sapere aude!

Logical addition (disjunction)

A	B	F=A∨B
0	0	0
0	1	1
1	0	1
1	1	1

A	B	A ∨ B
True	True	True
True	False	True
False	True	True
False	False	False

BOOLEAN LOGIC

AND Both terms | **OR** Either term | **NOT** Only one term

+0.1 from to fin Exq

Good logic


Socrates was a philosopher

S ∈ Φ


philosophers are men

Φ ∈ A


Socrates was a man

S ∈ A

Bad logic


Socrates was a man

S ∈ A

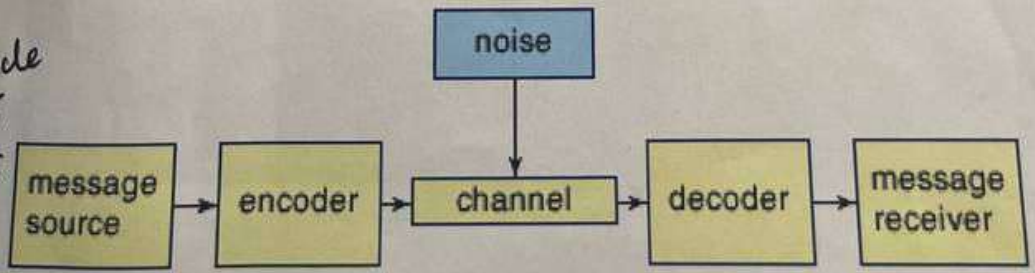

philosophers are men

Φ ∈ A


Socrates was a philosopher

S ∈ Φ

+0.1
to fin Grade
by Feb 25
Handout



(Shannon)

Resume of Lecture by Pr. Bob Gallagher from 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 conribution 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.

(1)

Logic continues to b
abused in politics,
religion and most n
scientific areas

Famous German figures

P. Kant Gauß M. Goethe W.

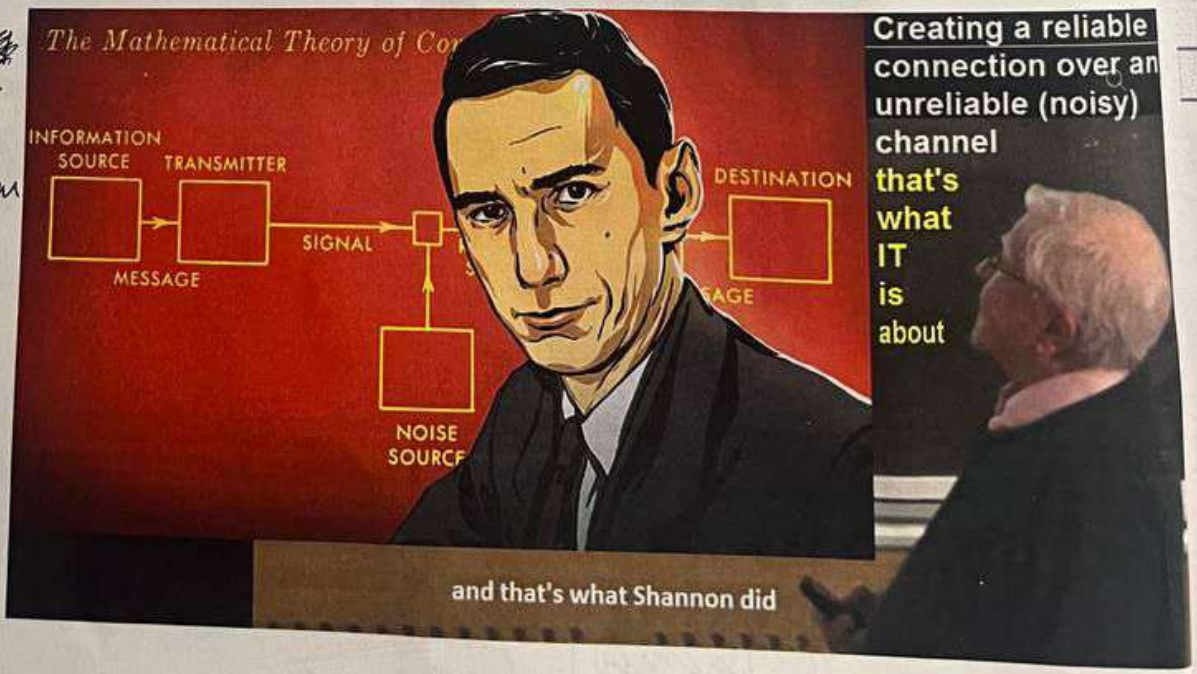
A little nationalistic, but this is an sample of right logic

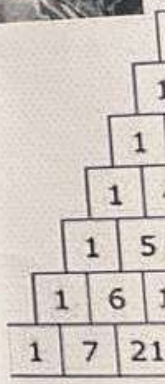
Kant, Gauss, Goethe are great → Kant, Gauss, Goethe - Germans → Germany Great

Hrg. steps

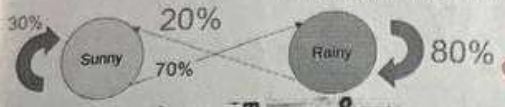
Bad logic (abuse of logic)

What did Shannon do while developing information theory? What is information theory is about? (2)





Markoff Chain Probability Model for Oxford Weather



① listening
② first way of processing
③ Writing, incl. sth. you're not quite sure about

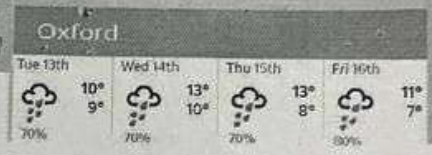
← What is this? (3)

School gravity MOTION ==formalism==> University $E = mc^2$

Motivation: 80% chance of rain

Let A_j be the event of rain at 9am on day j of this term, $1 \le j \le n$

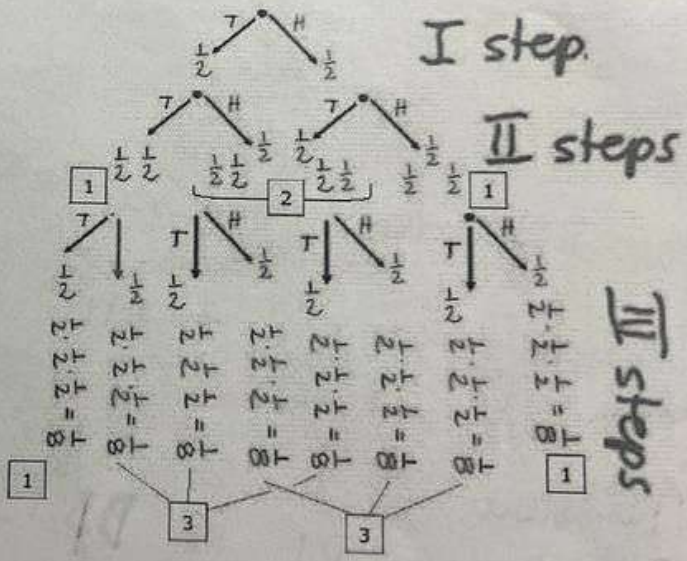
Suppose the events A_j each have probability p, independently



(9)

Pascal's triangle

1								← 1
1	1							← 2
1	2	1						← 4
1	3	3	1					← 8
1	4	6	4	1				← 16
1	5	10	10	5	1			← 32
1	6	15	20	15	6	1		← 64
1	7	21	35	35	21	7	1	← 128



Newton's Binomial

$$(a+b)^0 = 1$$
$$(a+b)^1 = a+b$$
$$(a+b)^2 = a^2+2ab+b^2$$
$$(a+b)^3 = a^3+3a^2b+3ab^2+b^3$$
$$(a+b)^4 = a^4+4a^3b+6a^2b^2+4ab^3+b^4$$
$$(a+b)^5 = a^5+5a^4b+10a^3b^2+10a^2b^3+5ab^4+b^5$$

(7) A parity bit is a simple error-checking tool used in digital data transmission or storage
It's (extra bit added to a set of bits to check if the data is correct.

(8) The images - visual metaphors used in i.t., particularly about error correction and redundancy. In common systems.
TOP IMAGE: a visual metaphor for redundancy. The character

Encoding the number 7.

7 In binary: 7 = 0111

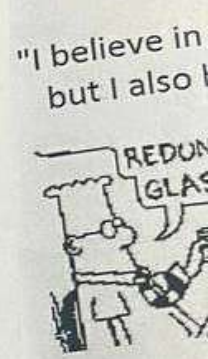
Position 1 2 3 4 5 6 7
Bits ? ? 0 ? 1 1 1

Positions: 1 2 3 4 5 6 7
Bits: P1 P2 D1 P3 D2 D3 D4

Data bits 0111 into positions 3(D1), 5(D2), 6(D3), 7(D4)
Then calculating parity bits P1, P2, P3

1. P1 (1357) → covers ?011 → 0+1+1 = 2 (even) → P1 = 0
2. P2 (2367) → covers ?011 → 0+1+1 = 2 → P2 = 0
3. P3 (4567) → covers ?111 → 1+1+1 = 3 (odd) → P3 = 1

So: Position: 1 2 3 4 5 6 7
Bits: 0 0 0 1 1 1 1



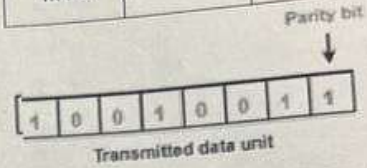
Source Tr	
sequence	
s	
0	
1	

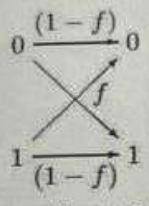
The repetit

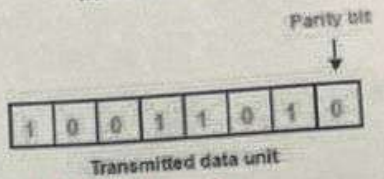
7.

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

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

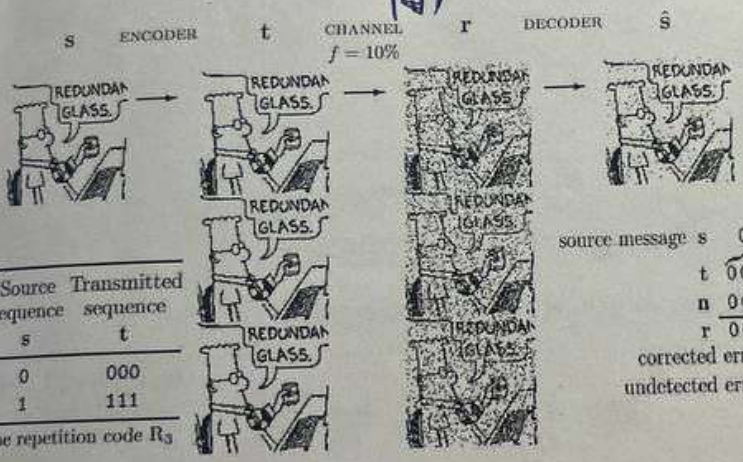






(8)

What is Parity Bit? (7)

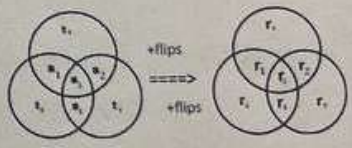


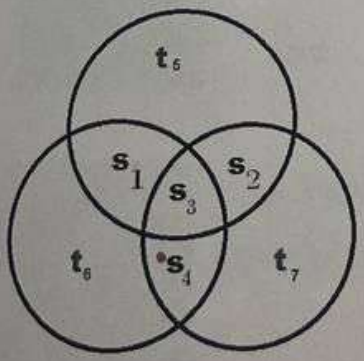
Source sequence s	Transmitted sequence t
0	000
1	111

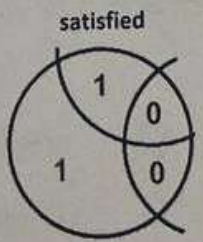
The repetition code R_3

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					*		

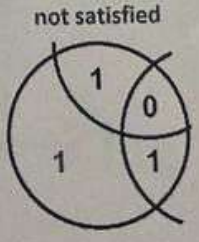
7.4. Hamming code. $\frac{4}{\Sigma} \rightarrow \frac{7}{t}$



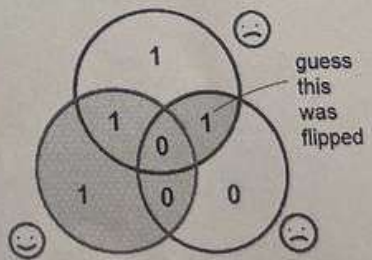




1+1+0+0=**0**



1+1+0+1=**1**



Hamming 7.4 means: You take 4 data bits, add 3 parity bits, and send 7 bits total

AM (Amplitude Modulation) → Volume changes

FM (Frequency modulation) → Pitch (speed) changes

Reginald A
(October 6, 186

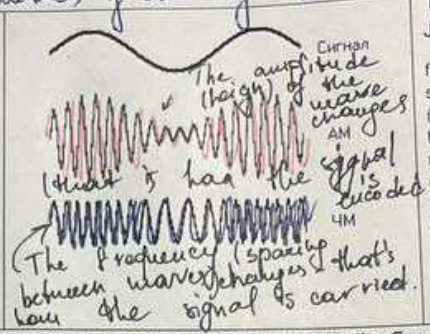
"Ни одна орг
деятельност
области или
пока она не
University P

Battle of
(3 month 3
10.07-31.1

H. N

a comparation of AM and FM methods of encoding information onto a radio wave.

Reginald A. Fessenden
(October 6, 1866 – July 22, 1932)

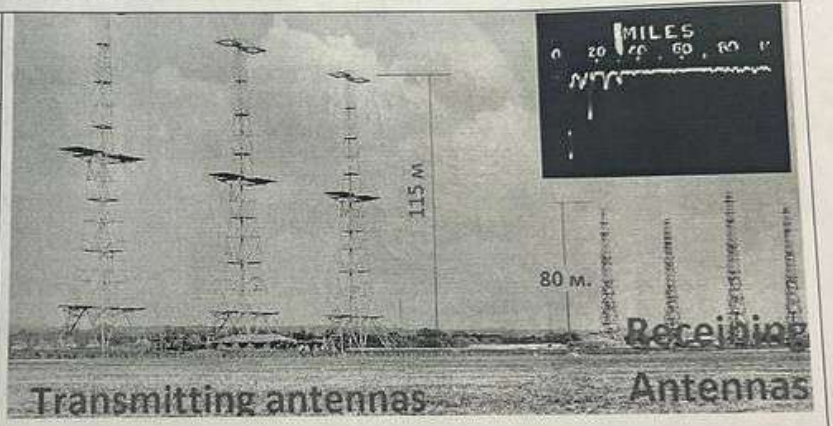


(October 6, 1866 – July 22, 1932)

first transmission of speech by radio (1900), and the first two-way radiotelegraphic communication across the Atlantic Ocean (1906)

"Ни одна организация, занимающаяся какой-либо конкретной областью деятельности, никогда не изобретает какие-либо важные разработки в этой области или не внедряет какие-либо важные разработки в этой области до тех пор, пока она не будет вынуждена сделать это из-за внешней конкуренции.." Oxford University Press. The Quarterly Journal of Economics , Feb., 1926, p. 262.

Battle of Britain
(3 month 3 weeks)
10.07-31.10.1940



Radar played a major role in the Battle of England

H. Nyquist

$$W = K \log m$$

Where W is the speed of transmission of intelligence,
m is the number of current values,
and, K is a constant.

Ralph **Hartley**
(81:1888-1970)

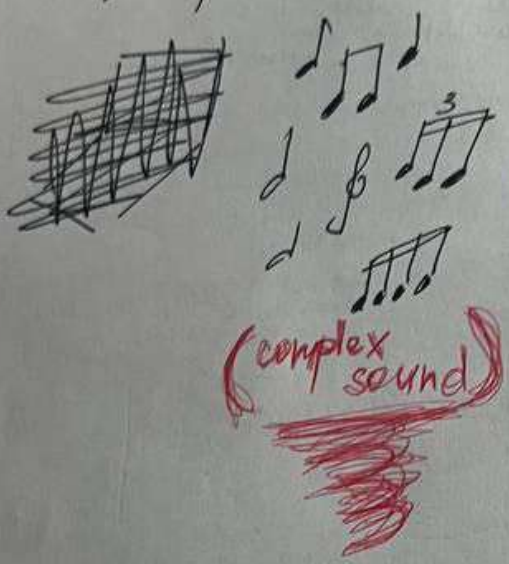
$$H = n \log s$$

$$= \log s^n.$$

(4) What is Fourier transform?

It's a mathematical tool that turns signal from the time domain into the frequency domain

Example:



It's made of many notes (frequencies) played together

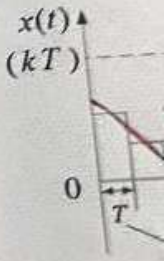
Fourier Transform breaks it down to show: | Which notes are present
| How strong each one is

Fourier Transform = from time → to frequency

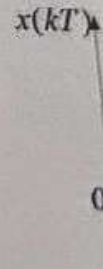
It helps us to see the hidden waves inside any signal - used in:

- Music
- Signal processing
- Image compression
- Medicine (like MRI)

Sampling

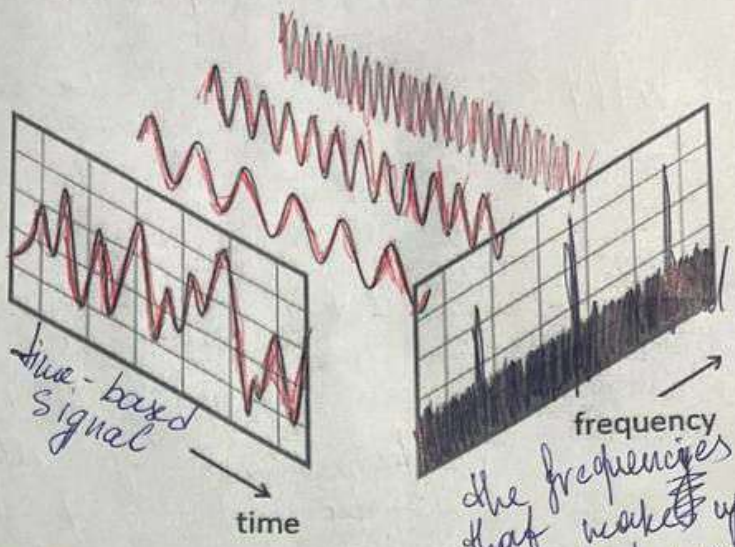


Time inte
(kT) are



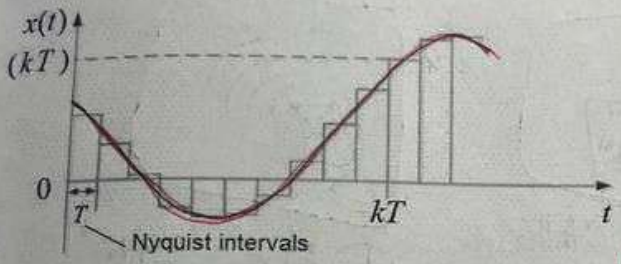
What is Fourier transform? (4)

Fourier transform



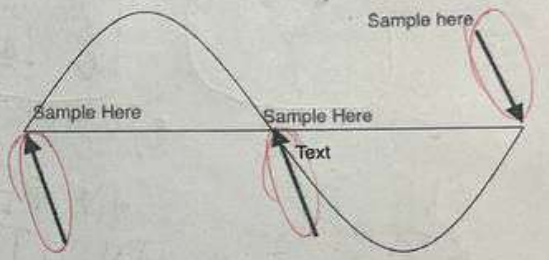
the frequencies that makes up that wave

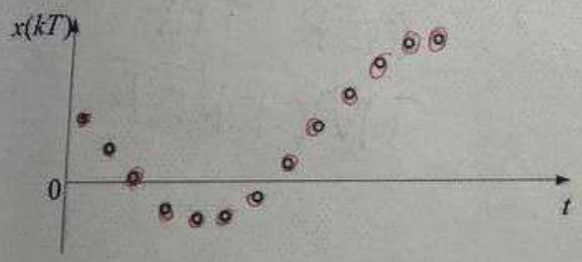
Sampling. Kotelnikov-Nyquist Theorem

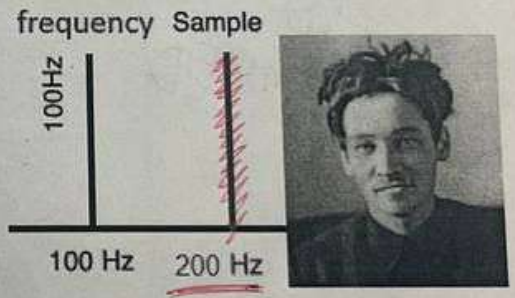


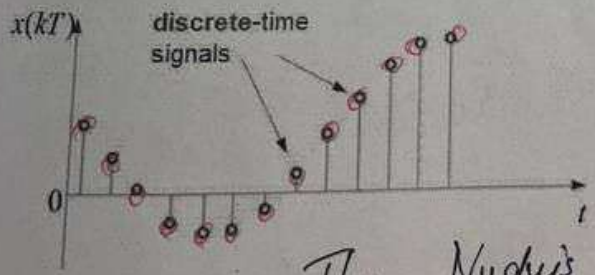
Time intervals T, through which readings s (kT) are taken, are called Nyquist intervals.

Sine with period T — Sampling at T/2 (5)









$F_{sample} >= 2 * F_{max}$

$(T_{sample} <= T_{min}/2)$

(6)

Vladimir Kotelnikov

The Nyquis theorem tells us: to perfectly capture a signal, you must sample it at least twice the highest frequency in it

(5) Sampling – taking regular snapshots of a continuous signal to store or process it digitally

WHY? computers can't handle continuous data – so we "sample" it at regular time intervals

(6) Vladimir Kotelnikov: independently discovered the Sampling theorem, which is foundation of all digital audio, video and communication

Thanks to him

• MUSIC CAN BE STORED AND STREAMED

• PHONE CALLS CAN BE DIGITIZED

• DATA CAN BE TRANSMITTED OVER THE INTERNET

Yes / No game of 20 questions

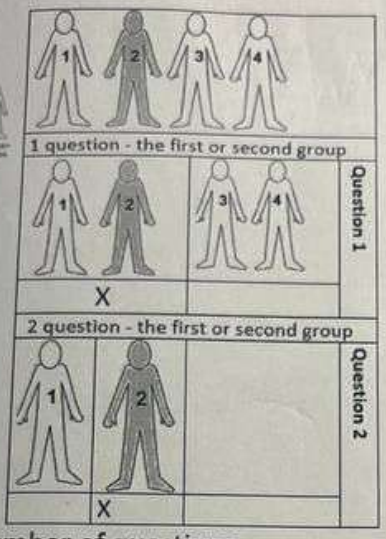
Say **NO** to the **first**

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

Average number of questions =

1*0.5+	2*0.25+	3*0,125+	3*0,125
			



Average number of questions =

2*0.25+ 2*0.25+ 2*0,25+ 2*0,25 =2

Question 1. Is this Zuckerberg?	 50%	1*0.5
Question 2. Is this Sergey Brin?	 25%	2*0.25
Question 3. Is this Stefan from BMW?	 12,5%	3*0,125
So Prince Saud	 12,5%	3*0,125
Average number of questions =		1,75

using the probabilistic grouping and decision trees to minimize entropy

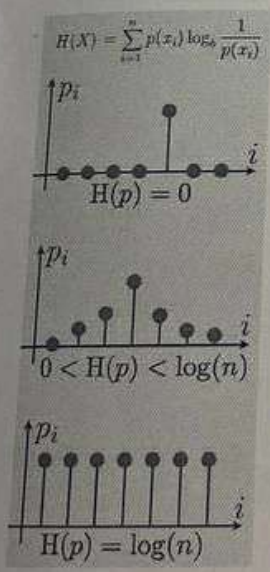
50 billion | 25 billion | 12.5 billion | 12.5 billion

Mark Zukerberg P(1)= **50%**

Sergey Brin P(2)= **25%**

Stefan Quandt P(3)= **12,5%**

Prince Al Saud P(4)= **12,5%**



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

Quantifying information

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

number of bits required to encode choice

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

Mathematical expl. of the Shannon Entropy

ABBA - take a chance about probability.

$A_1 B_1 B_2 A_2$
$A_1 A_2 B_1 B_2$
$\vdots$
$A_2 A_1 B_2 B_1$

$\frac{4!}{2!2!}$

ABBAT $\rightarrow \frac{5!}{2!2!1!}$

TALLIN $= \frac{7!}{1!1!1!2!2!}$

$\frac{120!}{5!} = \frac{6!}{3!}$

6!

$A_1 A_2 A_3$ BCD distinguishable.

indistinguishable

$BA_2 DA_1 A_3 D$
$BA_1 DA_2 A_3 C$ → 3!
$BA_1 DA_3 A_2 C$

BAAB }
BBAA } 4

$B_1 B_2 A_1 A_2$
$B_2 B_1 A_1 A_2$

− 2 } 4 $\frac{4}{4!}$

$B_1 B_2 A_2 A_1$ − 2
$B_2 B_1 A_2 1$

$n! = (1 \cdot (n-1)(n-2) \dots 2 \cdot 1)$

Vowels Consonants

$P(A) = \frac{m_1! \cdot m_2!}{n!}$ ← $n - m_1$

$m_1 + m_2 = n$

```
#using System;
class ABoole
{
  public static void Main()
  {
    Console.WriteLine("Hello Projecto
  }
}
```

$$\frac{n!}{n_1! n_2! \dots n_k!}$$

$k - 2 \rightarrow$

Aristotelian logic

- Who: Aristotel
- Based on: Categories (All, some, none)
- Examples
  - All humans are mortal
  - Socrates is human
  - Socrates is mortal
- Used in: Philosophy, reasoning

Boolean logic

- Who: George Boole
- Based on: True/False (1 or 0)
- Uses: AND, OR, NOT
- Examples:
  A = true, B = false
  A AND B = false
- Used in: Computer and electronics

Project o

parity bit -

энтропия по Хартли

$H = n \log s = \log s^n$

шифрование по [illegible]

[illegible]

(2.) Shannon created a mathematical framework that describes how information is transmitted through a communication system.

He: • Broke down communication into key components:

1. Information source
2. Transmitter
3. Channel
4. Noise source
5. Receiver
6. Destination.

• Analyzed how information can be ~~[illegible]~~ encoded, sent and decoded reliably even in the presence of noise.

Difference between them two!

A: Words and logic in statements

B: Math-like with true/false values

Заместителю директора
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образовательным
инновациям
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получения высшего
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Объяснительная

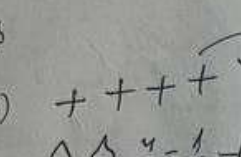
tigobay

сатовее

сальвадор
дали

50%.

2 questions



$\frac{1}{8} = \frac{1}{4} = 0.125$ 12%.
0.125 12.5%.

1) + $1 \cdot 0.5 = 1 \cdot \frac{4}{8} = 0.5$
2) ♠ $2 \cdot 0.25 = 2/8 = 0.5$
3) ★ $3 \cdot 0.125 = 3\ \frac{1}{8} = 0.325$
3) ♡ $3 \cdot 0.125 = 3\ \frac{1}{8} = 0.325$
$1,75$

$$\frac{+++ \spadesuit\spadesuit + \heartsuit}{8} = \frac{4+4+6}{8} = \frac{14}{8} = 1.75$$

14 | 8
8 | 1,75
60
56
40

+++++ 5/8
♠ 1/8
★ 1/8 3)
♡ 1/8 3)

0,375
0,375
1,750
5
0,625

1) $1 \cdot \frac{5}{8} = 0,625$
2) $2 \cdot \frac{1}{8} = 0,5$
3) $3 \cdot \frac{1}{8} = 0,375$
3) $3 \cdot \frac{1}{8} = 0,375$
$= 1,875.$

(3)
a
some
amo

If

religion

(1) "in politics"

may be abused when:

1. Politicians use misleading arguments to persuade or manipulate
2. Populist rhetoric replaced debate
3. Decisions are made for emotional or ideological reasons, ignoring facts

"in religion"

b. may be bypassed or distorted when:

1. Beliefs are asserted without evidence and then defended through circular reasoning
2. Faith is used to dismiss logical incon sistencies or avoid scrutiny
3. Appeals are made to tradition or authority instead of reason

"most non-scientific areas"

1. Pseudoscience
2. Conspiracy theories
3. Marketing and adv.
4. Social media arg.

(3) Image shows a Markov Chain which is a mathematical model used to describe how something changes from one stage to another based on probabilities

2 Weather states: Sunny ☀

Rainy 🌧

If its Sunny: 70% chance it stays Sunny tomorrow
30% it is going to be Rainy

If its Rainy: 80% ch. it stays Rainy
20% ch. it becomes Sunny

Key idea of M.C.:

It assumes that the next state only depends on the current state, not the whole history. This is called Markov Property

(9) What is Pascal triangle?

Pascal's Triangle is a triangle of numbers where:

- Each number is the sum of the two numbers directly above it
- The triangle starts with 1 at the top.

Why created?

To help with math problems like:

- Counting things
- Solving equations
- Figuring out chances

Difference between information and data
Data are raw facts and figures without context, while information is processed data that has meaning and usefulness.

Subject of research in information theory
Information theory studies the quantitative characteristics of information and the methods of its transmission, storage, and processing.

Markov chains
Markov chains are mathematical models that describe systems comprising states and transitions, where the probability of the next state depends only on the current state.

Control codes
Control codes are mechanisms used to detect and correct errors in data during transmission or storage.

N R3
N R3 denotes the space of three-dimensional vectors with real coordinates represented as R^3.

Hamming code
Hamming code is an error-correcting method that adds redundancy bits to the original data for protection against errors.

Amount of information on Hartley
The amount of information according to Hartley is measured in bans and is defined as the logarithm of the number of possible messages.

Amount of information on Shannon
Shannon's amount of information considers the probabilities of messages and is measured in bits, reflecting uncertainty.

Concept of entropy
Entropy is a measure of uncertainty or randomness of a random variable, indicating the average amount of information.

Hartley definition of entropy
Hartley entropy is defined as the logarithm of the number of possible states of a system.

Shannon entropy
Shannon entropy generalizes Hartley's definition, taking into account the probabilities of different states.

Entropic compression of information
Entropic compression is the process of reducing the volume of data without loss of information, based on statistical properties of the data.

Probabilistic way of measuring information
This method measures information based on the probability of occurrence of an event, such as through entropy.

Nyquist interval
The Nyquist interval defines the maximum frequency that can be captured without aliasing for signal transmission.

Fourier transform
The Fourier transform converts time-domain signals into frequency representation, allowing analysis of frequency components.

Kotelnikov-Nyquist theorem
This theorem states that to reconstruct a signal, it must be sampled at least at twice the maximum frequency of the signal.

Pascal's Triangle
Pascal's Triangle is a tabular representation of binomial coefficients, used in combinatorics.

Binomial distribution
The binomial distribution describes the number of successes in a series of independent trials with two possible outcomes.

Boolean algebra and Aristotelian logic
Boolean algebra is a system for working with truth values, while Aristotelian logic focuses on rules of inference and syllogism.