KAIST

School of
Computing
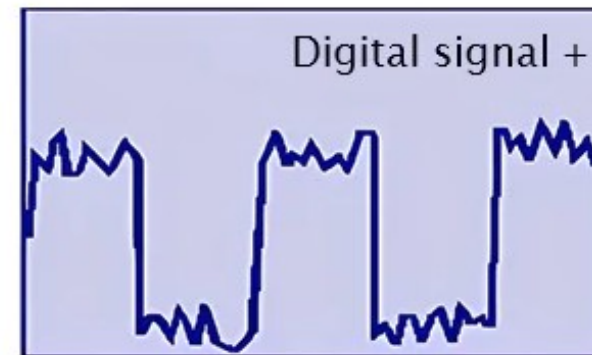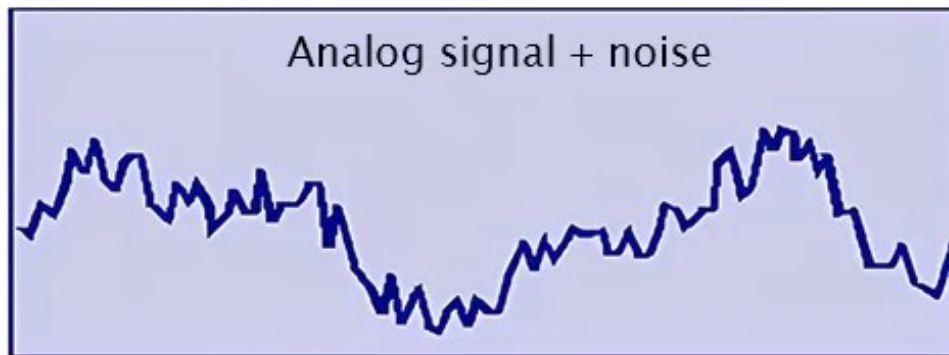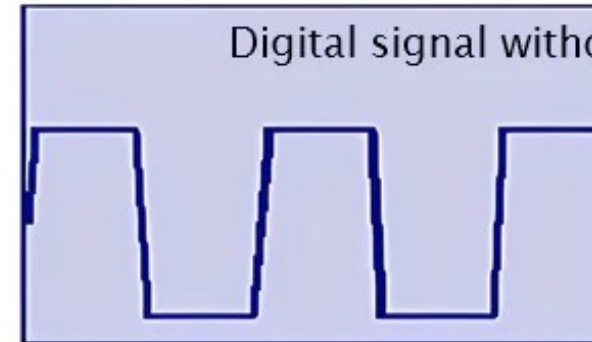
*Un*conventional
Computing

Martin Ziegler

CS492A in Fall 2024

§1 Conventional Computing

- Digital vs. Analog Signals

- Digital Models of Computing

- Examples and Discussion

- Electro-/Mechanic Digital Computing

- Fluidics + Soliton Computing

- Church-Turing Hypothesis

§1 Digital vs. Analog

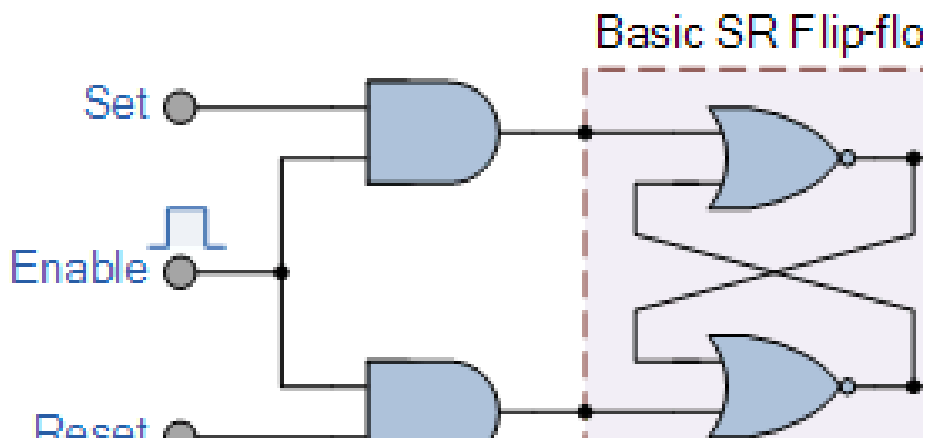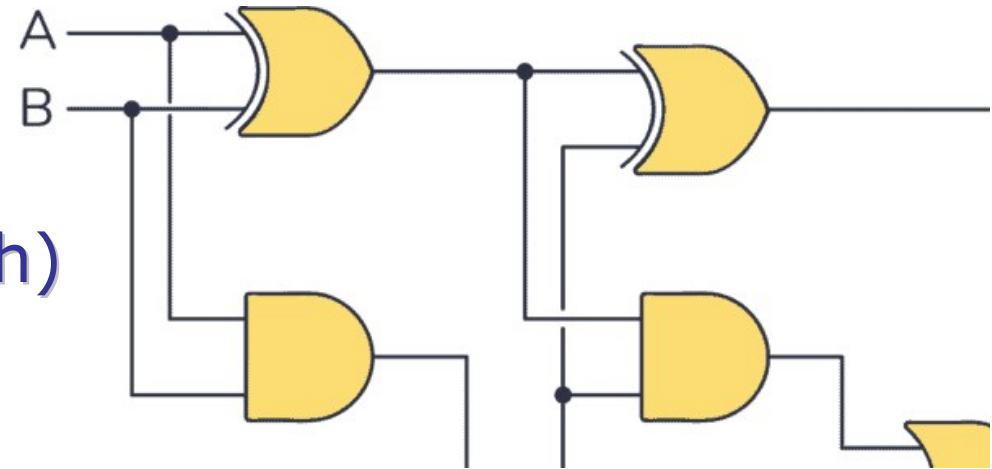|	
Analog signal without noise	Digital signal witho
Analog signal + noise	Digital signal +
Signal recovered from noise loses detail	Signal accurately recove

§1 Digital Models of Computing

- Boolean gate

- Boolean circuit
  (=directed *acyclic* graph)

- Boolean circuit
  with latches/feedback

- *Arithmetic* circuit
  with/out memory

- Finite-State Machine/Automaton
  (FSM/FSA)

- BLOOP program, Turing Machine
  = FLOOP = WHILE program

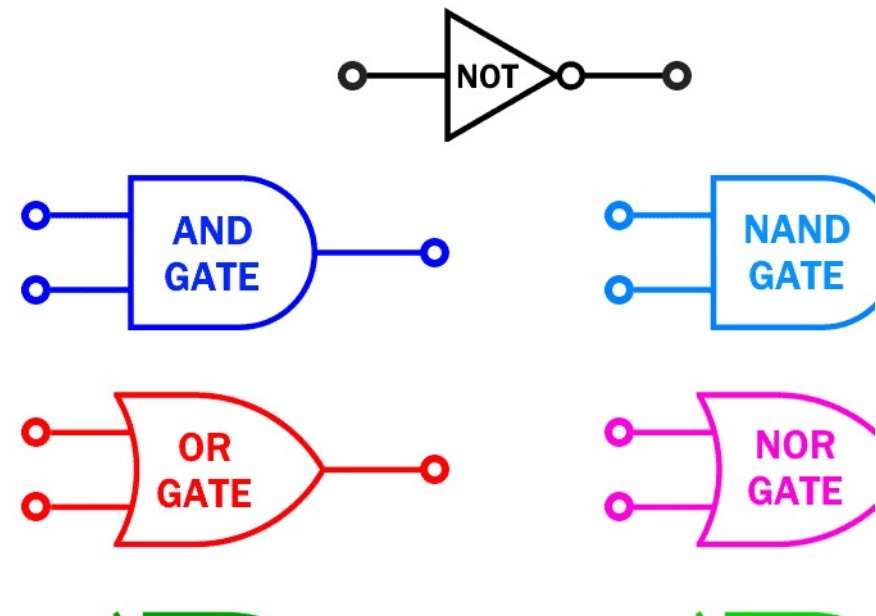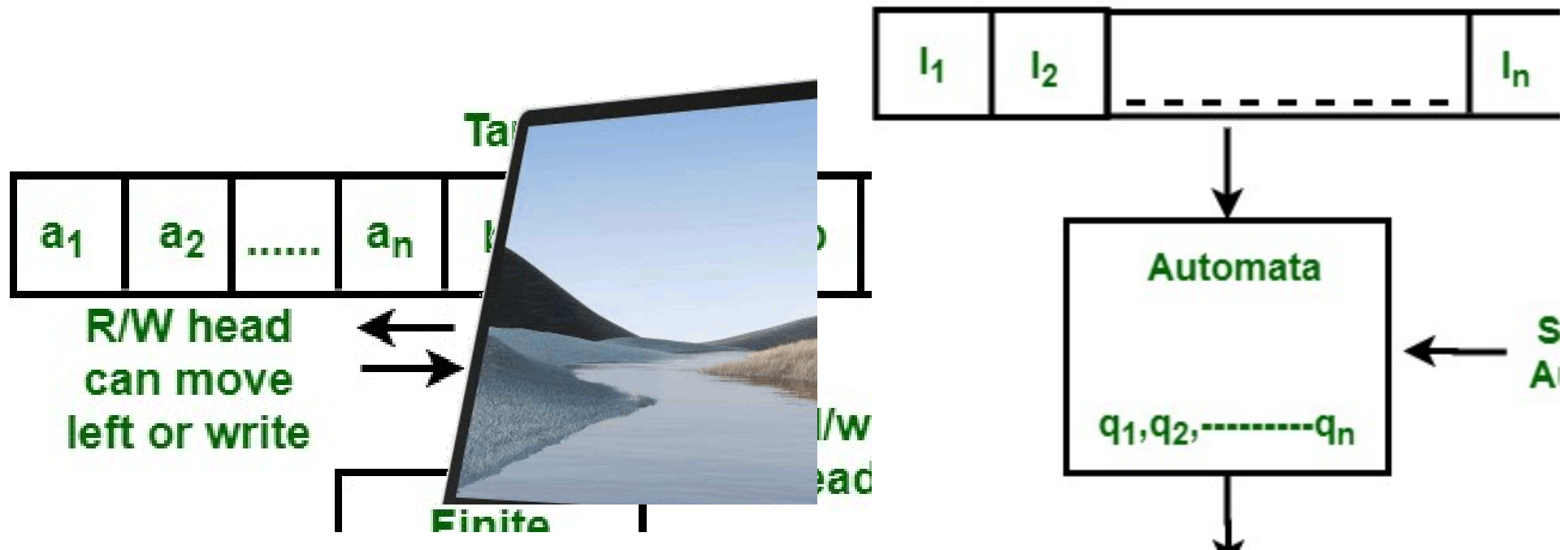- High-level program. languages

high-level program.

obj.librar

Computer

Hardware
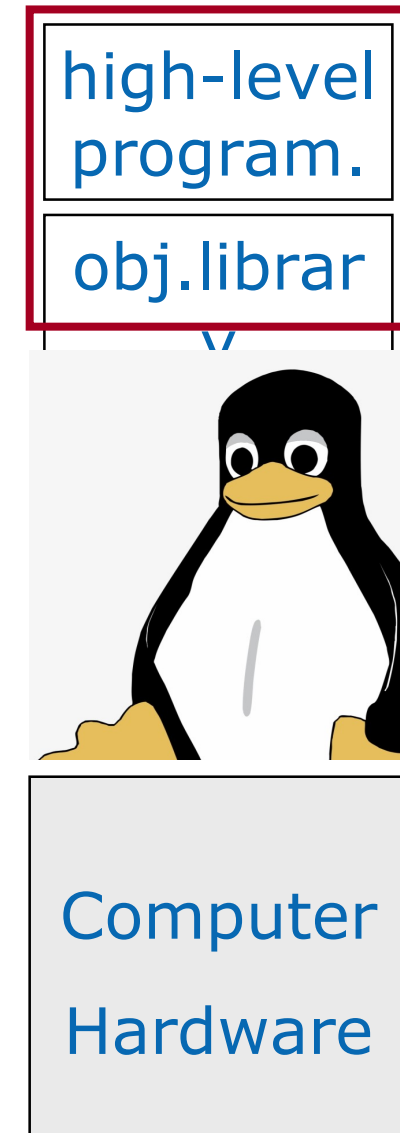
§1 Discussion&Examples

- Boolean gate

- Boolean circuit
  (=directed *acyclic* graph)

- Boolean circuit
  with latches/feedback

A ─

B ─

Types of Basic Logic Gate

NOT

Basic SR Flip-flo

Set

Enable

Reset

AND GATE

OR GATE

NAND GATE

NOR GATE

§1 Discussion&Examples

- Finite-State Machine/Automaton (FSM/FSA)   CS322

- BLOOP program, Turing Machine = FLOOP = WHILE program   CS422
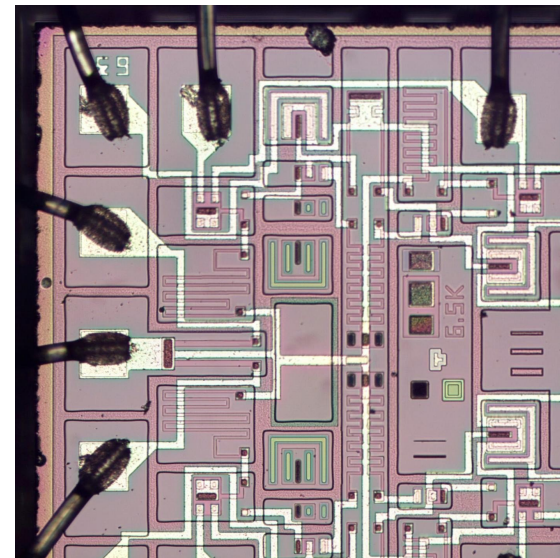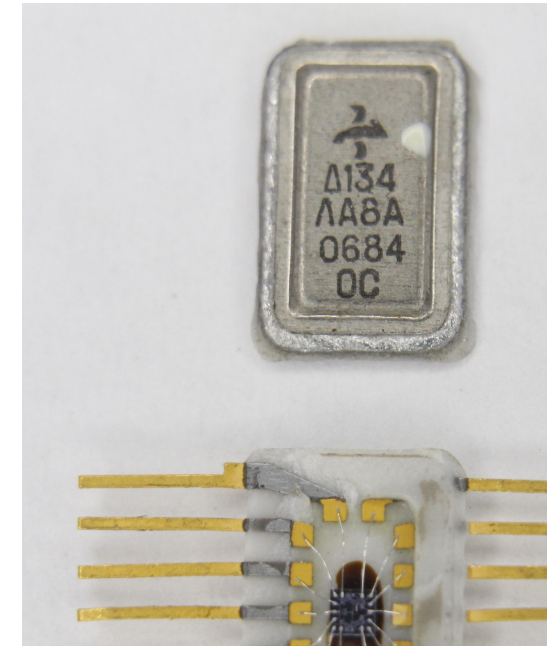
- High-level program. languages   CS320

§1 *Electronic* Digital Computing
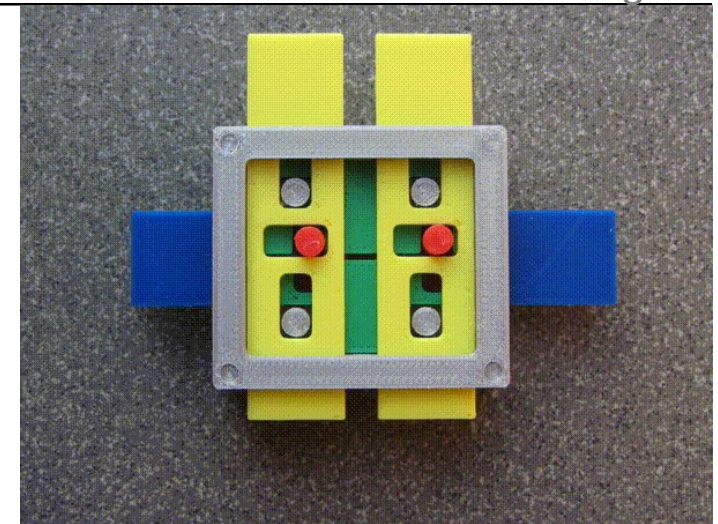
- **Boolean gate**

- **Boolean circuit**

§1 *Mechanical* Digital Computing

- Boolean gate

- Boolean circuit

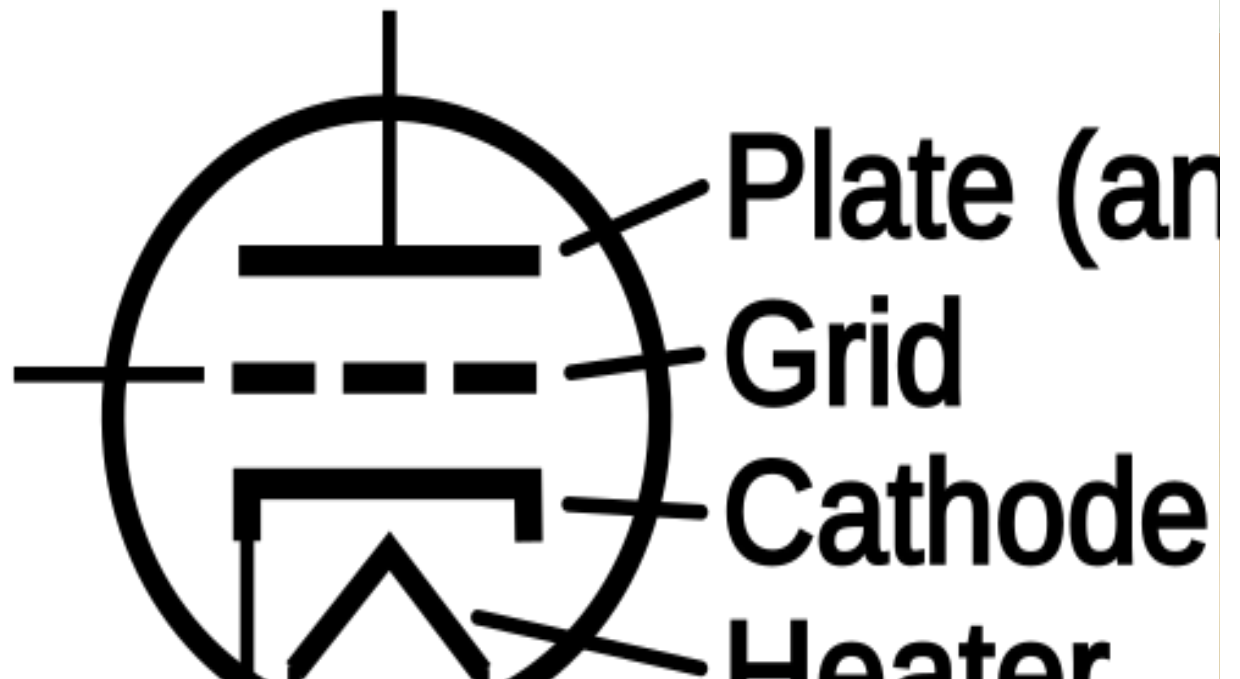 Zuse Z1 (1935~37)

  clock 1Hz, weight ≈1t

`http://electrickery.nl`

§1 *Electromechanic* Computing

- Boolean gate

- Boolean circuit

Faulty!

Zuse Z**2** (1938~39)

clock 1**0**Hz, weight ≈**0.3***t*
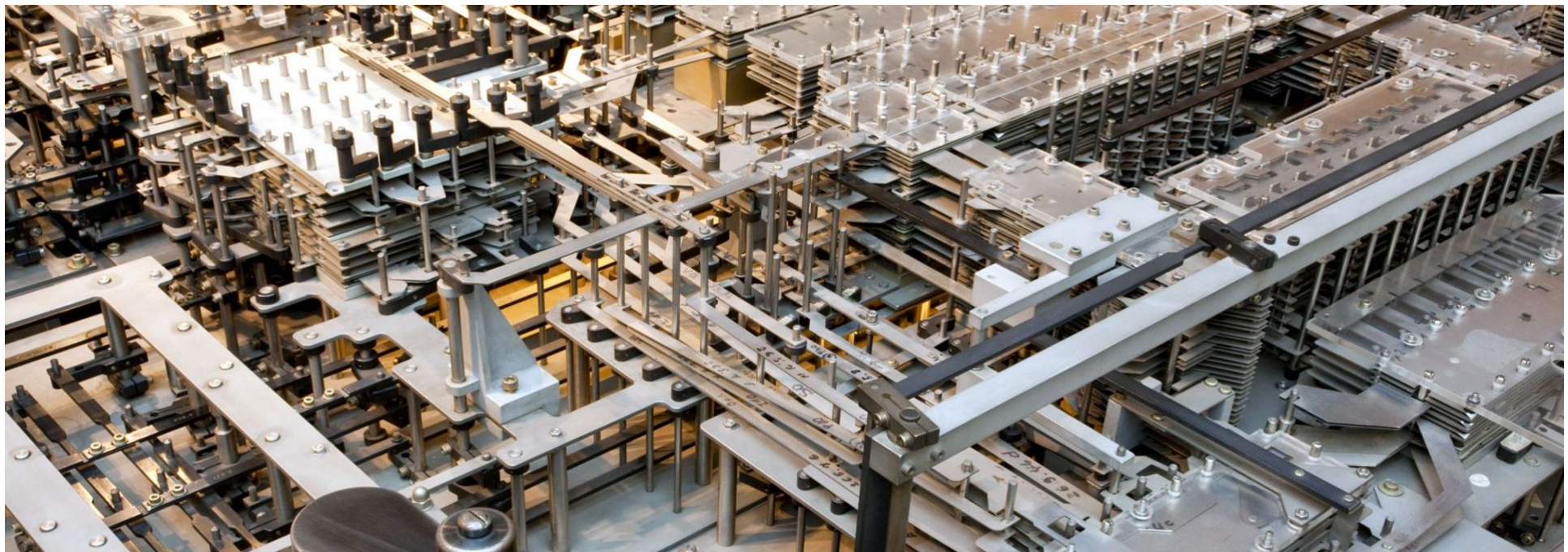
§1 *Electric ≠tronic* Computing

- Boolean gate

- Boolean circuit

±200V

Glas

Ar

Gr

He

cat

He

Plate (an

Grid

Cathode

Heater

§1 *Colossus* (UK'1943~45)
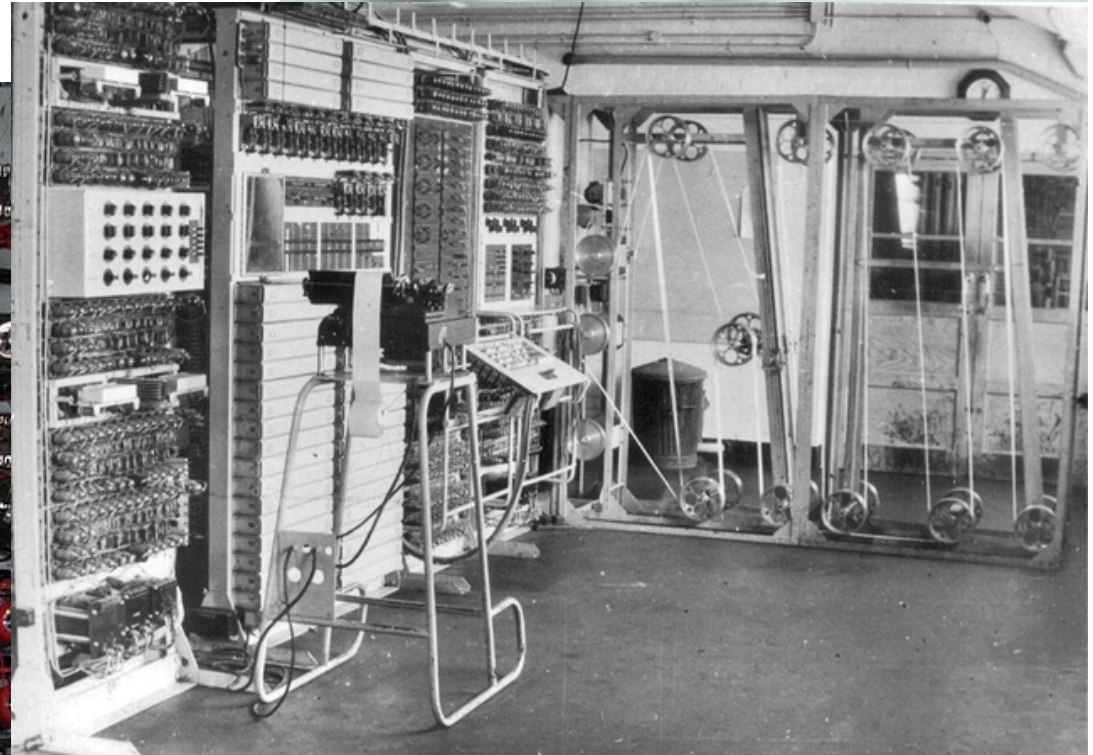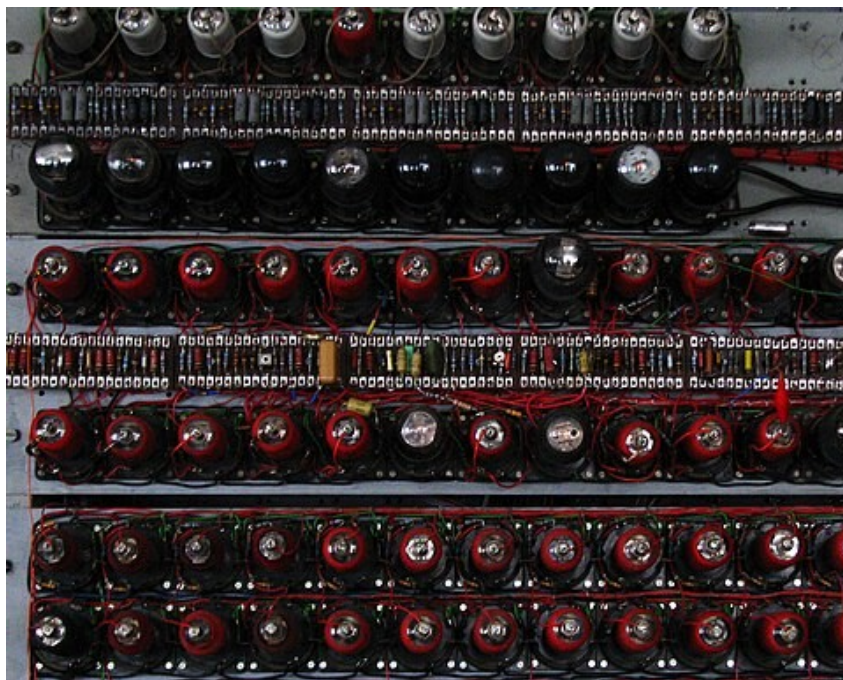
- Boolean gate

- Boolean circuit
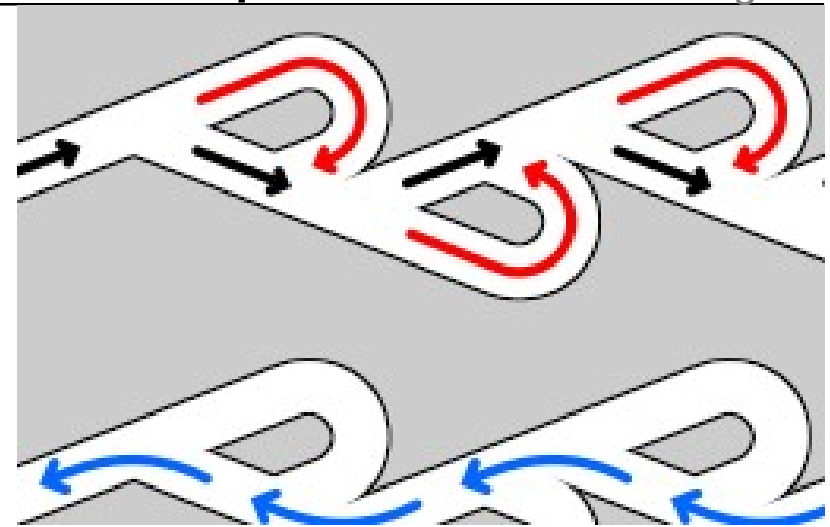
§1 Fluidics

=liquids and/or gases,
no moving "hard" parts

- Boolean gate

- Boolean circuit

Tesla Valve

Fig. 1

§1 Fluidics

=liquids and/or gases,
no moving "hard" parts

- Boolean gate
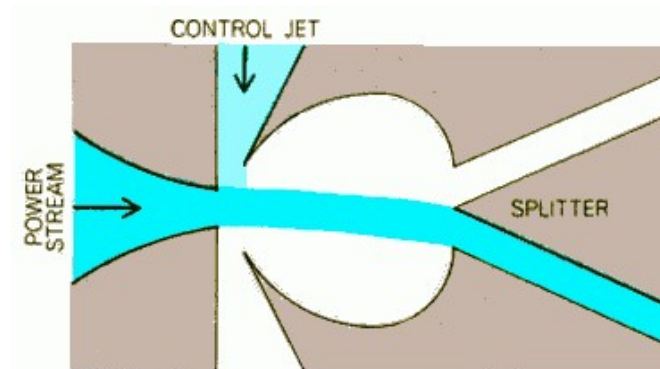- Boolean circuit

$\overline{A} \cdot \overline{B}$

A

R
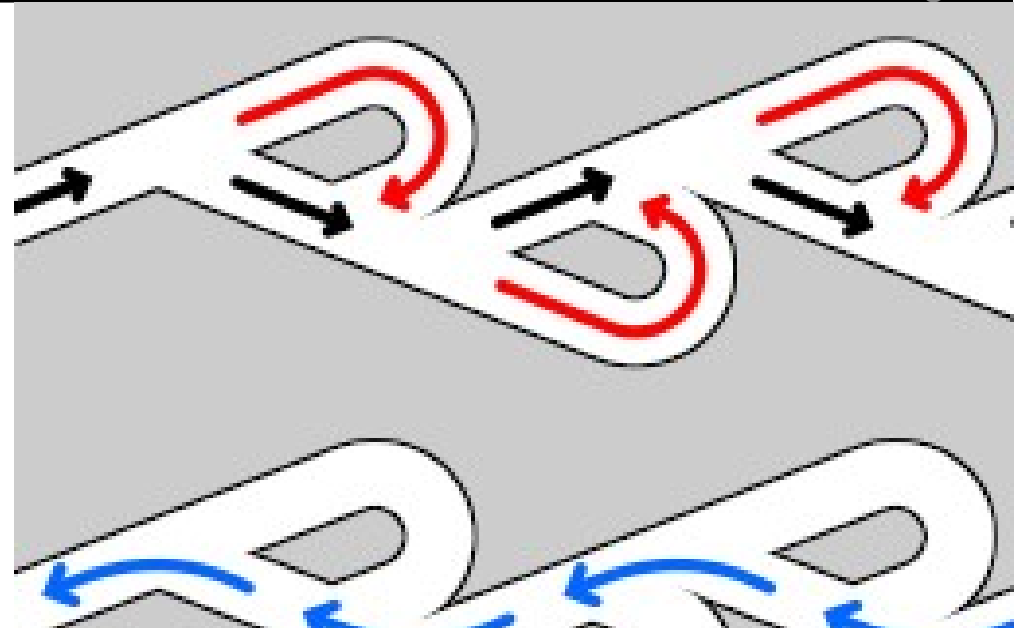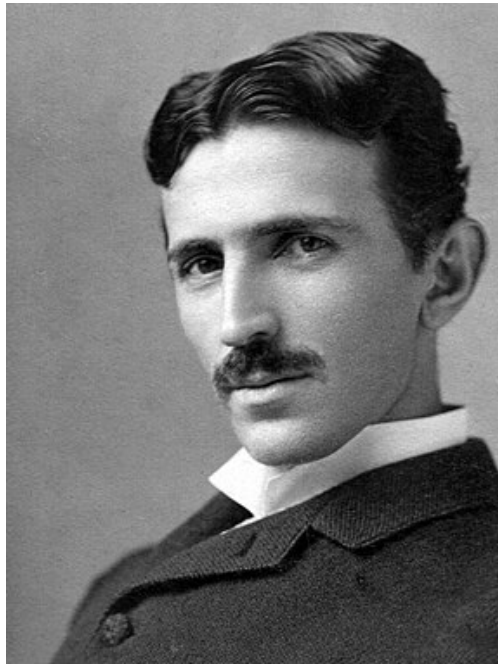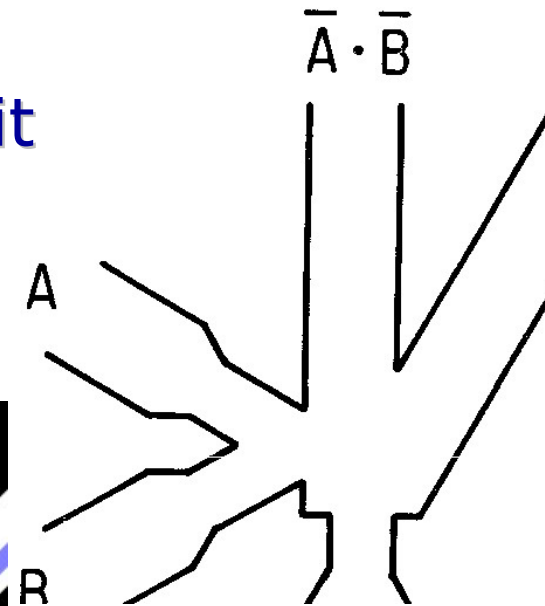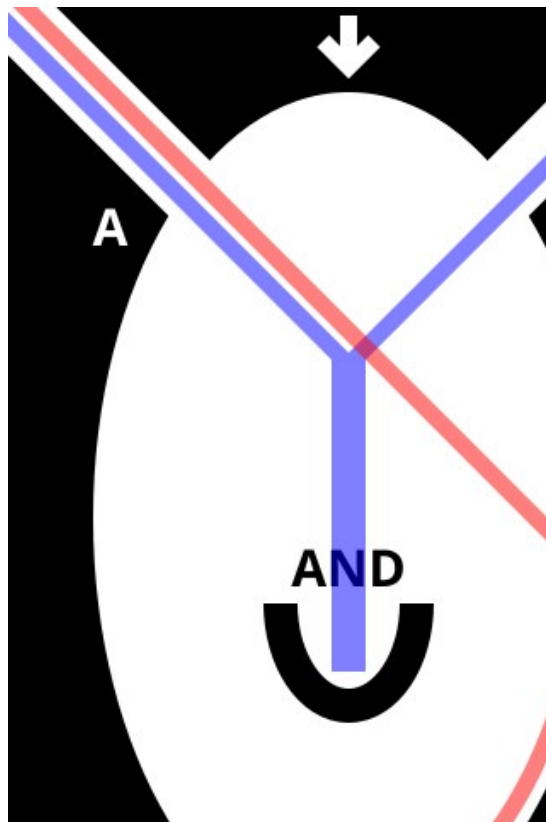
"FLODAC"

Gluskin&Jacoby&Reader (1964)

AND

CONTROL JET

POWER STREAM

SPLITTER

CONTROL JET
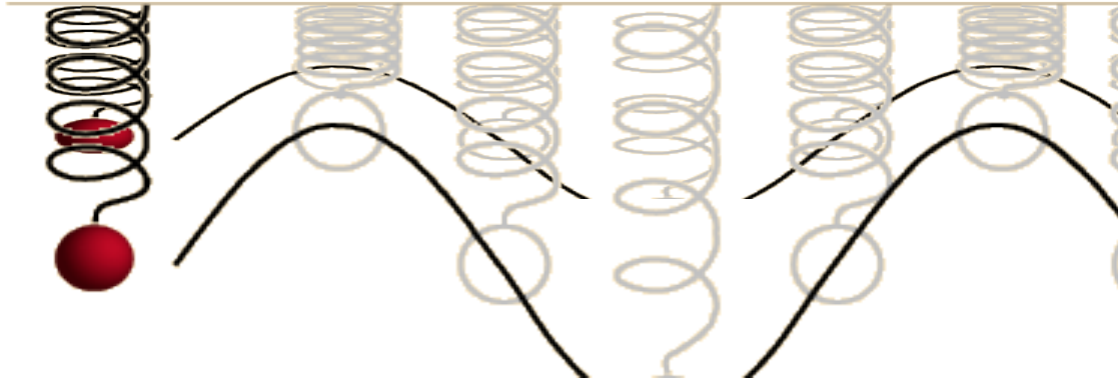
Amplifier
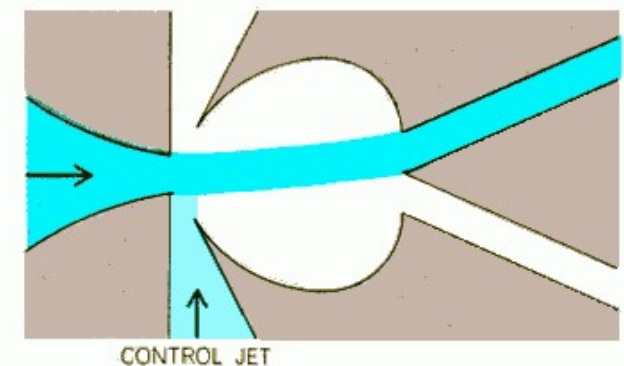
§1 Wave Physics Recap

Wave Equation

$$\Delta u = c \cdot \ddot{u} + f$$

linear,

velocity c

e.g. sound
(*not too loud*)

or EM waves
(*not too strong*)

§1 *Non*linear Wave Recap

Elastic Limit

Force

Extension
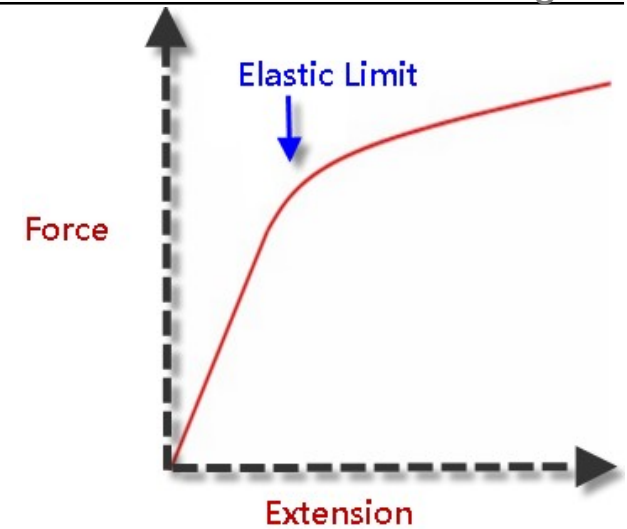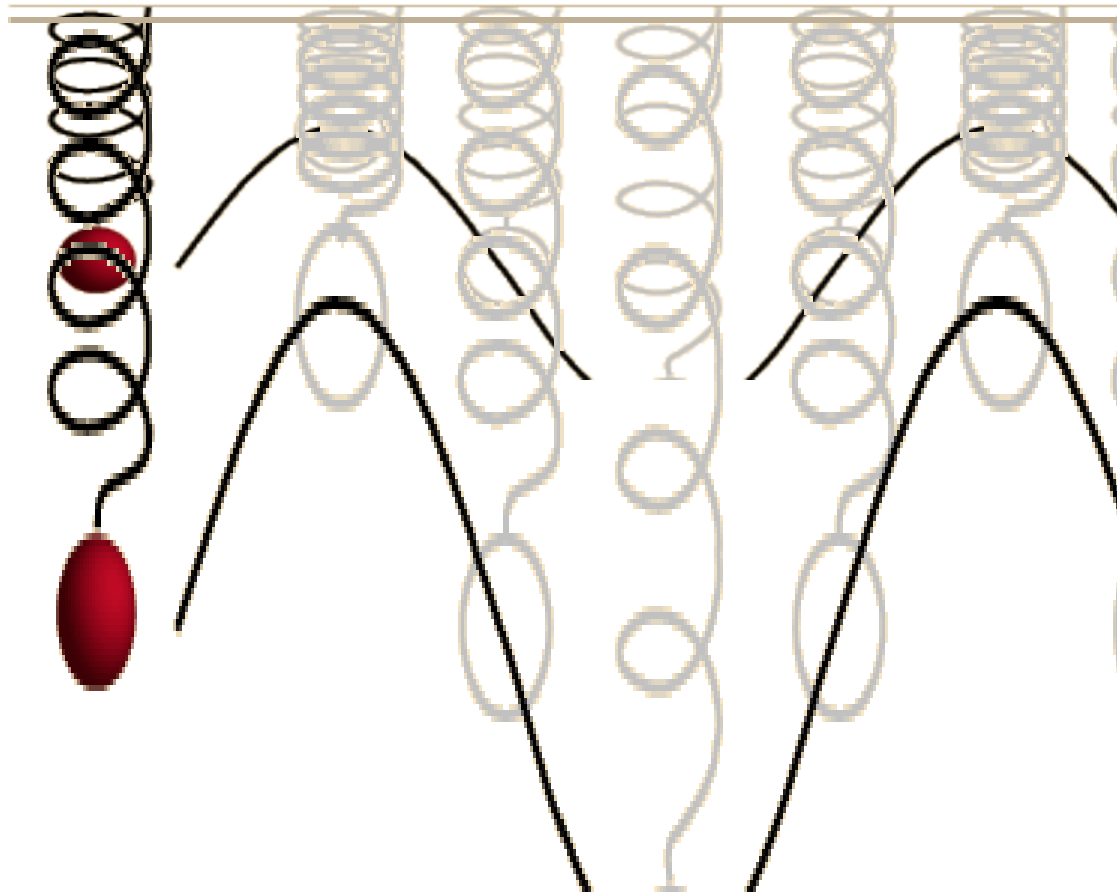
Navier–Stokes Equations (viscous)

$$\partial_t \underline{u} - \Delta \underline{u} + (\underline{u} \cdot \nabla)\underline{u} + \nabla P = f$$

$\beta = 0.8$

$\beta = 0.4$

$\beta = 0.2$

1.0

Velocity

0

-1.0
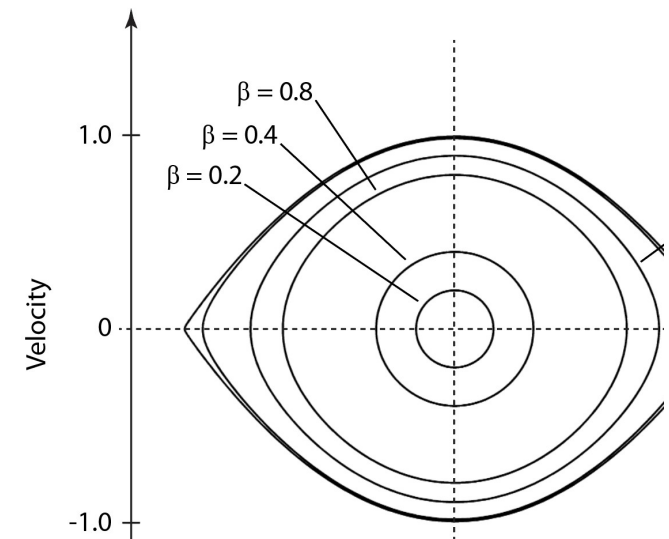
§1 *Soliton* Recap

Shallow water

Laser/ optical fiber

Korteweg–de Vries Equation

$$\partial_t u - 6\, u \cdot u' + u'^{\,3} = f$$

§1 Optical *Soliton* Computing

Multimode solitons

Linear

Nonlinear

Intense visibl

Multimode fib

Multiple filamentation

Light conde

Left-handed
Circularly polarized light

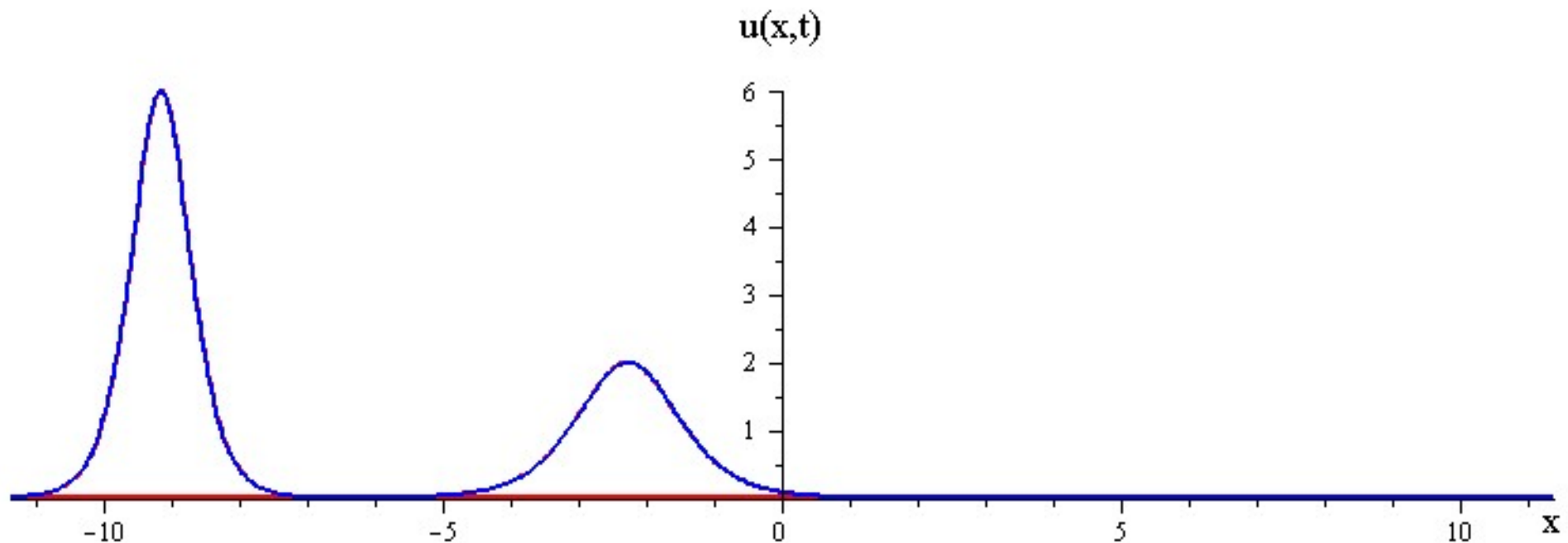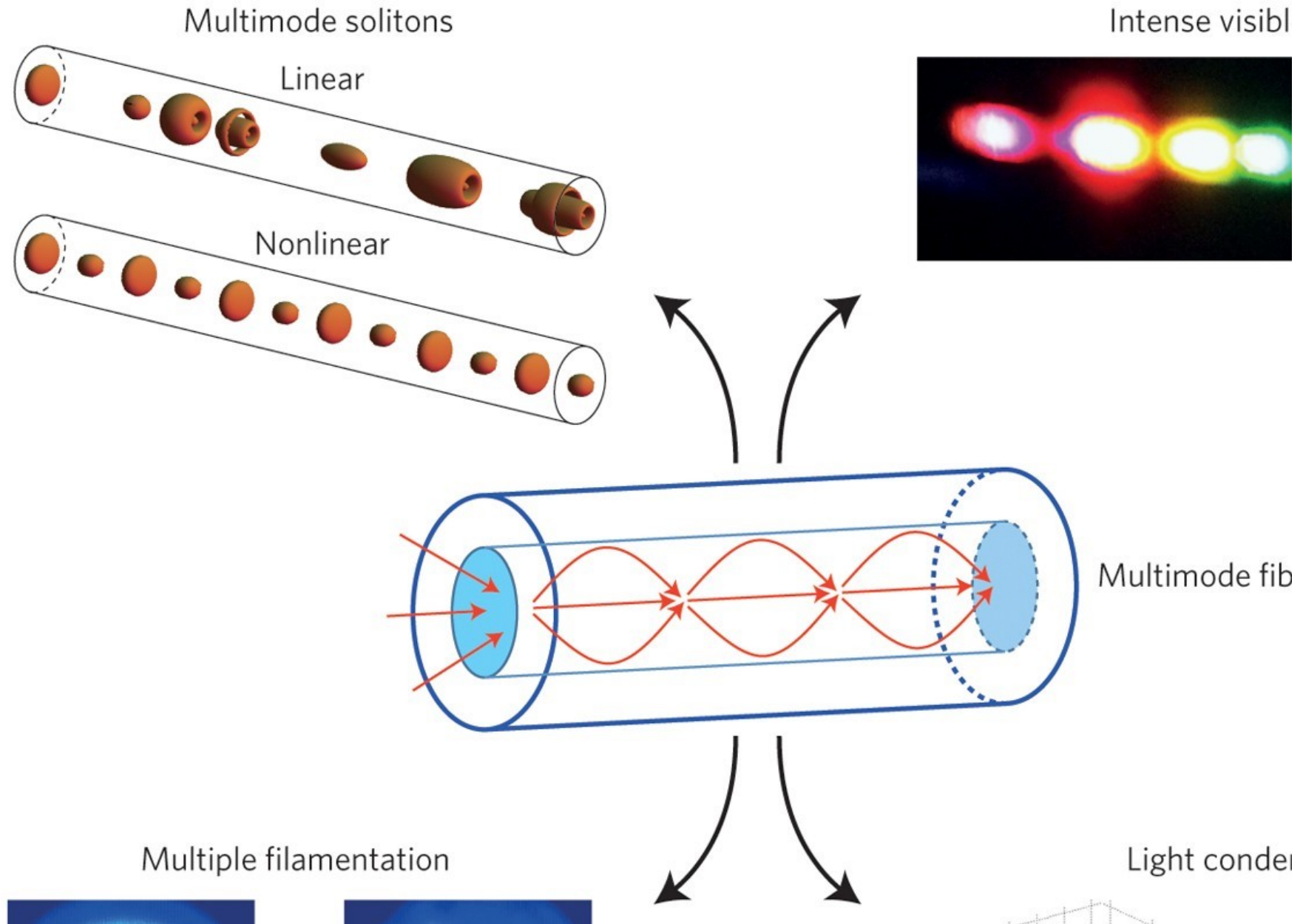Linearly polarized Light

Unpol

(a)

z = 100

Input	Output
$A_1 = 0$ $A_2 = 0$	$B = 0$

(b)

z = 100

Input	Output
$A_1 = 1$ $A_2 = 0$	$B = 1$

(c)

z = 100

Input	Output
$A_1 = 1$ $A_2 = 1$	$B = 0$

(d)

z = 100

Input	Output
$A_1 = 0$ $A_2 = 1$	$B = 1$
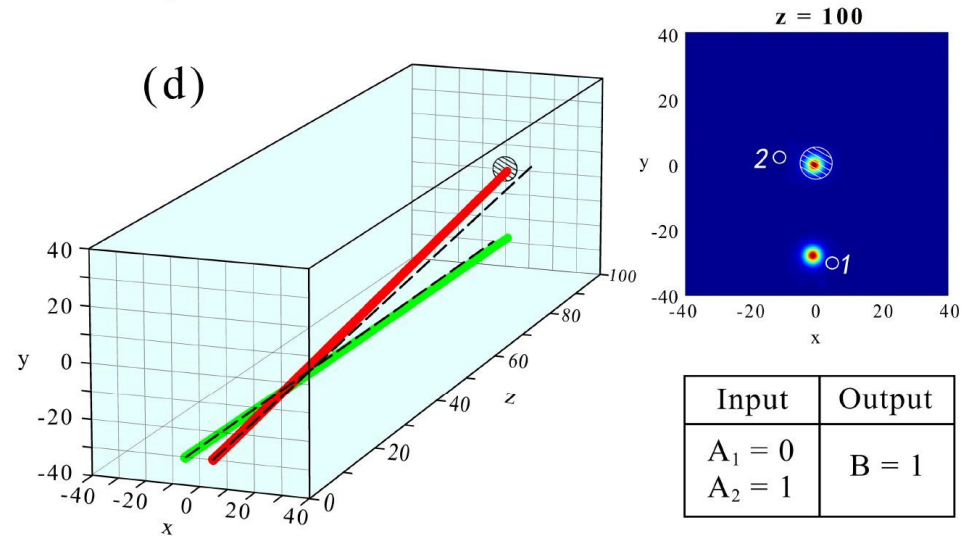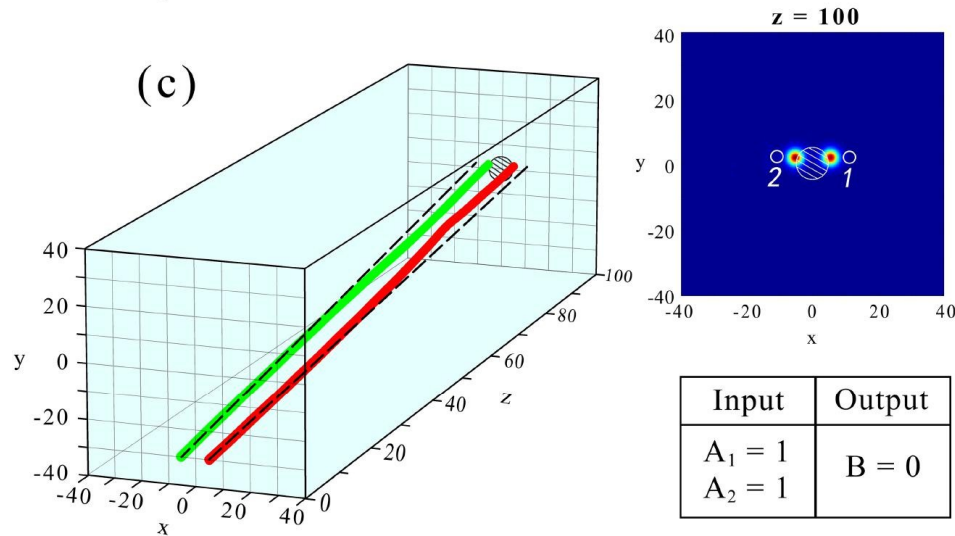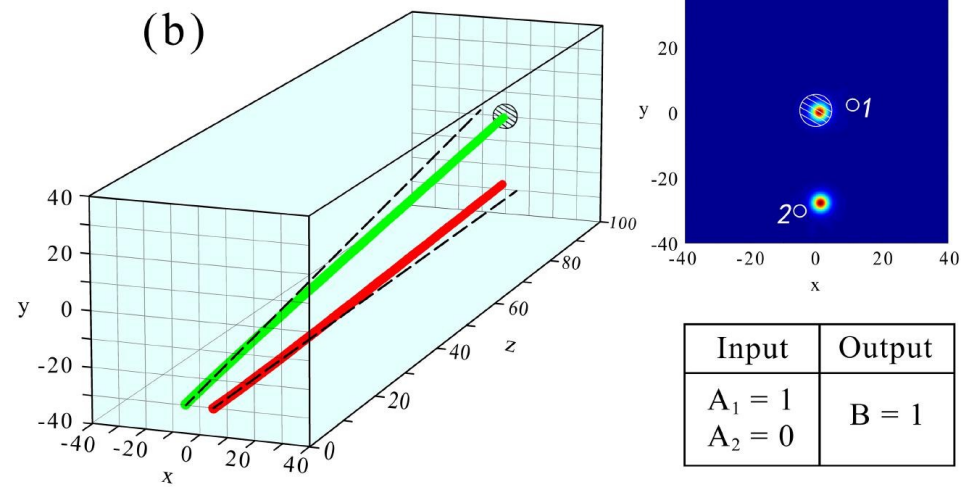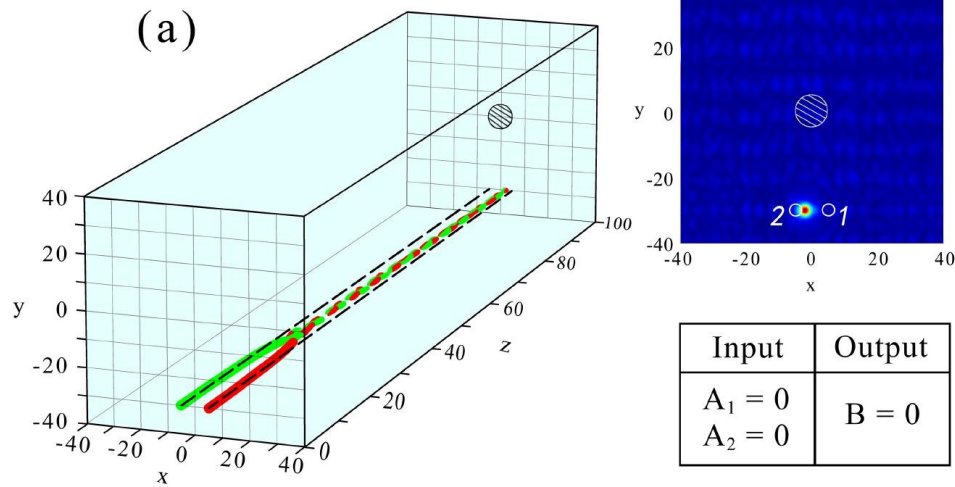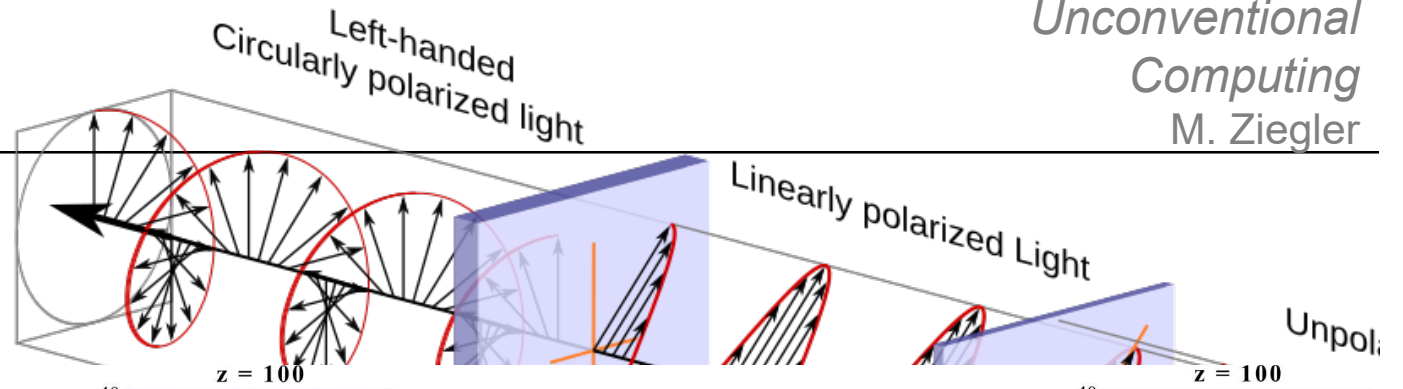
§1 Church-Turing *Hypothesis*

Church-Turing Thesis: For $f:\mathbb{N}\to\mathbb{N}$ TFAE:

qualitative: no efficiency

- f is computable by a Turing machine
- f is computable by a WHILE/FLOOP program
- f is µ-recursive
- f is definable in λ-Calculus

Mathematically proven by Kleene, Church, Rosser '36

Strong (Physical) **Church-Turing *Hypo*thesis:**

a) Any $f:\mathbb{N}\to\mathbb{N}$ computable by a *physical* device can also be computed by a Turing Machine.

in polyn. time

b) Any $f:\mathbb{N}\to\mathbb{N}$ computable by a Turing Machine can also be computed by a *physical* device.

Recall question: Is your PC a Turing machine or not?

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