Mechanism as a philosophy

- René Descartes’ mechanist view of physical nature did not include a view of the mind as a machine—only bodies.
  - The French, in particular, delighted in making clockwork machines that mimicked human and animal motions.
  - This automaton monk kicks his feet, beats his chest with one hand, waves with the other, turns his head, rolls his eyes, and opens and shuts his mouth.

The machine as a mind

- But the reductionist view that it fostered was easily extended to include minds.
- What can a machine do that is like what a mind can do?
  - A manageable task might involve numbers, since explicit rules exist for manipulating numbers to add, subtract, multiply, divide, etc.
Manual devices to automate calculation

- The abacus – from Babylonia, 5000 years ago (at least).
- Abacus from the Greek αβακος = board or tablet.

Early written number systems were cumbersome and did not facilitate calculation – possibly because they were only intended to record the result of a calculation on an abacus.

- At right, Egyptian hieroglyph for the number 4622.
- Or consider Roman numerals:
  - CCCXIX + DCCVIII = MXXVI

A better notation system

- The abacus was widely used in Europe until just a few hundred years ago.
- Hindu (i.e. Arabic) numerals and arithmetic entered Europe, but slowly.
- Eventually the use of Arabic numerals displaced the abacus because the notation system facilitated computation.
Logarithms

- John Napier (1550-1617) invented logarithms in 1614.
- Logarithms turned multiplication and division into addition and subtraction of exponents.

Napier’s “bones”

- Napier also invented his “bones” or rods, a system of turning multiplication into a mechanical task.

The slide rule

- The combination of using logarithms and mechanical rods was the slide rule.
The slide rule “ruled”

- The slide rule became the standard tool for complex engineering calculations until the latter part of the 20th century.
  - Major engineering projects, such as the Golden Gate Bridge in San Francisco, were built using calculations made on simple slide rules.

The mechanical calculator

- Wilhelm Schickhard invented the mechanical calculator in 1623
  - He was an acquaintance of Johannes Kepler
  - Schickhard called his invention the calculating clock. (It had a gear mechanism.)
  - His device was lost to history because of the Thirty Years War, which began in 1618.
  - Schickhard died of the plague in 1635.

Mechanical Calculator Reinvented

- Blaise Pascal (1623-1662)
  - Invented another version of the “calculator,” really an adding machine
  - Leibniz had another version but it was lost until 1879.
Powered calculators

- An idea of the Industrial Revolution
  - Logical source of power: steam engines.
  - Problem with that: Steam engines deliver lots of power, but they are not delicate.

A Boulton-Watt steam engine installed in a factory.

The need for massive calculations

- The Navigator’s Table
  - The British National Almanac published a navigator’s table to assist ships finding position at sea.
  - Errors in it were responsible for some ships running aground or being lost.
- Reliable and reproducible tables were needed.

The problem with logarithmic tables needed

- Logarithmic tables reduced complex multiplication and division problems to simpler addition and subtraction procedures.
- But were the tables themselves accurate?
**Accurate logarithmic tables needed**

- In 1784 the government of France set out to draw up new tables of logarithms and trigonometric functions.
  - Six mathematicians devised the method of calculation.
  - Seven or eight foremen supervised 70-80 people who did calculations.
  - Took 2 years. Resulting in 2 hand-written copies.
  - It was never published for fear of errors being introduced. The copies were stored in the Paris library.
  - Despite the care taken the tables were full of errors.

**Charles Babbage**

- Conceiver of the mechanical computing machine.
  - Got the idea while a student at Cambridge in 1812-1813.

**Babbage’s proposal**

- To build a machine that would calculate tables and stamp the answer on metal plates which could be printed from directly.
- A full-fledged engine could need thousands of precise gears and other parts.
- It would be the most demanding machine ever constructed.
- It was to be run by steam.
The project goes broke

- Babbage got funding from the British government and embarked on construction.
  - He spent £6000 of his own money and got £19,000 from the government.
- After 19 years, part of an engine had been completed (shown at right).
- The project was abandoned.

Impractical and still inaccurate

- The finished machine would have been 10 ft high, 10 ft wide, 5 ft deep, and weighed 2 tons.
- A Swedish version was built in 1850s.
  - Inferior, but completed
- None of these machines was accurate!
  - Mechanical gears jammed; metal parts wore down.

Babbage's Analytical Engine

- Meanwhile, Babbage came up with another scheme, to build a machine capable of solving “any mathematical problem.”
  - It was a thought experiment for Babbage – it was never built.
- The machine would be able to store numbers for use in a calculation.
  - It would have been the size of a locomotive.
**The punch card idea**

- Babbage’s Analytical Engine was intended to use punch cards to contain instructions to the computer.

  This was the principle of the Jacquard loom, which had automated complex weaving tasks.

**Punch cards for data**

- Herman Hollerith, an American inventor, adapted the idea of the punch cards as a means of recording data from the 1890 U.S. census.

**The Hollerith Tabulator**

- The tabulator only sorted and counted the data.
- It shortened the time required for the census data to be tabulated by several years.
The Tabulating Machine Company

- Hollerith founded a firm to make tabulators and other mechanical devices for business.
  - It merged in 1911 with 3 other firms, becoming the "Computing-Tabulating-Recording Company."
  - Later renamed "International Business Machines" – IBM

Office Machines

- Machines were already used in the office, e.g. the typewriter.
- A new occupation was created: The typist.

The mechanical calculator in the office

- The original "calculators" were really only adding machines.
The demand for number crunching

- Large-scale calculation became a major undertaking at the turn of the 20th century.
  - For example, in insurance companies, which employed hundreds of people to do manual calculations.

Binary arithmetic

- Until the mid-20th century calculating machines had worked by using the decimal number system.
  - 10 different digits required for each place value.
- But arithmetic works just as well with a binary system that just has zeros and ones.

The electric switch

- In a moment of insight, U.S. mathematical physicist George Stibity realized the connection between the on/off electric switch and binary arithmetic.
- It is far easier to build a machine that uses simple on/off settings than to mimic the 10 digits of our counting system.
The versatile logical operator

- Binary Arithmetic could also be used to perform symbolic logic operations.
  - Could add, subtract, multiply, divide.
- Just a matter of matching the choices:
  - On = 1 = true = north pole (on a magnet)
  - Off = 0 = false = south pole
- But this is a purely theoretical principle without a lot of engineering work.

The impetus of World War II

- A technical problem presented itself during the war: what is the optimal way to aim anti-aircraft artillery to hit their targets?
- There were many different models of cannons, and for each, the way to aim depended on their range, altitude of the target, air temperature, and the wind speed.

Firing Tables

- The chosen solution was to compile a firing table for each kind of gun.
- These were very difficult to construct.
- 2000-4000 trajectories per gun were needed, each required a series of complex calculations.
The Human Computer

- Tables were calculated by “computers” — i.e. people, who did calculations by hand, or with the help of an adding machine.
- A person could calculate one trajectory in 3 days.
  - Calculating trajectories from moving airplanes was virtually impossible.

The Moore School of Electrical Engineering

- During the war the US Army set up a computing station at the Moore School to calculate firing tables for each of its anti-aircraft cannons.

The Moore School at the University of Pennsylvania in Philadelphia.

The Moore School of Electrical Engineering

- The computing station used the latest in electronic technology, a differential analyzer, supplemented by desk calculators run by humans.

A differential analyzer — a mechanical device using analog principles to approximate waves.
**John W. Mauchly**

- 35 year old Assistant Professor at the Moore School.
- Mauchly proposed using vacuum tubes to build a high speed calculator.
- Maybe, he thought, it could calculate a trajectory in 100 seconds.
  - He overestimated the time by a factor of 3.
- In August 1942, Mauchly submitted a memo to the army and to the Moore School, which was ignored.

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**The formal proposal is submitted.**

- The war went on; the Army fell behind in calculating trajectories.
  - In March 1943, the man in charge of the Moore computing station heard of Mauchly's idea in a chance conversation.
  - He approached Mauchly to inquire about it.
  - Meanwhile Mauchly had lost the original memo to the Army.
- Mauchly was asked to submit a thorough proposal for an electronic calculator.
  - In April 1943, Mauchly handed in his proposal.

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**Project PX**

- The result of Mauchly's proposal, when finally accepted was the first electronic general purpose computer. It was called the ENIAC.
  - Electronic Numerator Integrator Analyzer and Computer
- It was finally finished in November 1945 (after the war), 3 months after the Japanese surrender.
- The ENIAC used decimal, not binary mathematics.
  - It operated at (relatively) high speed, was programmable, and general purpose but did not store programs.
The ENIAC

- Components:
  - 17,468 vacuum tubes.
  - 70,000 resistors.
  - 10,000 capacitors.
  - 1500 relays.
  - 6000 manual switches.
- Size:
  - 8 feet high.
  - 80 feet long.
  - Weighed 30 tons.
  - Used 174,000 watts of power.
- Efficiency:
  - Took about 2 days to set up and to solve a problem.

This photo was used again and again in news stories and advertisements, including a U.S. Army recruitment ad offering technical training on electronic devices.

With computing power comes military power

- The first use of the ENIAC was to calculate the feasibility for a proposed design for the hydrogen bomb.
- The original computers were all used for military purposes.

The Commercial Computer Industry

- John Mauchly and the ENIAC project engineer, John Presper Eckert established a company to build computers for commercial use.

Mauchly (left) and Eckert
**Stored Program Computers**

- The Eckert-Mauchly Computer Corporation received an order from the Army to build a computer that would store a program for later use.
- Mathematician John von Neumann developed a design that allowed all computer functions to be coordinated through a central processing unit (CPU).
  - The Eckert-Mauchly Corporation was sold to Remington Rand.

**The Universal Automatic Computer**

- Remington Rand (through its unit that had been Eckert-Mauchly Corp) built the first commercially available computer that could store programs and data, be started and stopped at any time and reprogrammed.

**The UNIVAC**

- The UNIVAC – (Universal Automatic Computer), was first built in 1951.
  - Among the first customers were the U.S. Census and General Electric.
The UNIVAC and the U.S. Election of 1952

As a publicity stunt for the computer, the U.S. television network, CBS, used a UNIVAC to predict the U.S. presidential election on election night in November 1952.

- At 9 p.m. EST with only 7% of the votes in, UNIVAC awarded 43 states and 438 electoral votes to Eisenhower and 5 states with 93 electoral votes to Stevenson.

The computer was right

- Pollsters had predicted a close election.
  - The programmers thought they had surely made a mistake, so they did not release their prediction.
  - They reprogrammed the computer and had it predict a toss-up at 10 p.m.
  - By midnight, they realized they had been right the first time.
- The actual result was 442 electoral votes for Eisenhower, 89 for Stevenson.
- CBS commentator Edward R. Murrow remarked: “The trouble with machines … is people.”

Second Generation Computers (1956-1963)

- Transistors replaced the large vacuum tubes in TVs, radios, and computers.
  - Result: shrinking sizes and faster speeds ever since.
- Early “supercomputers” built for atomic energy laboratories could handle enormous amounts of data but were too costly for general business use.
  - A key feature of the second generation computers: they replaced machine language (straight binary code) with assembly language, a short-hand version.
Computers enter general use in industry: 1960s

- Several firms enter (mainframe) computer manufacturing business:
  - Burroughs, Control Data, Honeywell, IBM, Sperry-Rand, etc.
- Features of these computers:
  - Printers
  - Tape storage
  - Disk storage
  - Memory
  - Operating systems
  - Stored programs

The IBM 1401

- IBM emerged as the most successful large computer manufacturer for industry.
- The IBM Model 1401 was the "Model T" of the mainframe computer industry.

Stored programs the key

- By 1965 most large businesses routinely processed financial information using second generation computers.
  - The stored program was the key to the viability of computers for general use.
Third Generation Computers (1964-1971)

- Transistors were (much) better than vacuum tubes, but still generated a great deal of heat, which could damage the sensitive parts of the computer.
  - Solution: The quartz rock.
- Integrated circuits (made from quartz) were invented in 1958.

The Semiconductor

- Next step: put many components on a single chip: the semiconductor.
- Another innovation of third generation computers: an operating system that allowed many programs to run at once, coordinated by a central program.

Fourth Generation Computers (1971- more or less the present)

- Miniaturization:
  - More and more components on a single chip.
  - LSI – Large Scale Integration, fit hundreds of components on one chip.
  - VLSI – Very Large Scale Integration, fit hundreds of thousands of components on one chip.
  - ULSI – Ultra-large Scale Integration, fit millions on a chip.
- Increase in power, efficiency, reliability.
- Decrease in price.
The Microprocessor

- Intel 4004 chip (from 1971) put all the components of a computer (central processing unit, memory, and input/output) on a single tiny chip.
  - Result: the microprocessor chip that could be used for multiple purposes.
- Common uses of microprocessors:
  - Microwave ovens.
  - Television sets.
  - Automobiles with electronic fuel injection systems.

The Microcomputer

- Computers for the general consumer arrived in the mid-1970s.
  - They came with user-friendly software, word-processing, spreadsheets.
- Pioneers: Commodore, Radio Shack, Apple Computers.
  - Early 1980s, video games (e.g. PacMan) were adapted for the microcomputer, increasing popular demand.

The Personal Computer

- In 1981, IBM introduced the PC (personal computer) for use in homes, offices and schools.
  - IBM clones, less expensive than the name brand, made the price even more affordable.
The Personal Computer

- Personal computers in use went from 2 million in 1981 to 5.5 million in 1982.
- Further developments:
  - Laptop
  - Palmtop (PalmPilot, Blackberry, etc.)
  - The Apple Macintosh (with icon-based user-friendly operating system), with the mouse.
  - Windows

Networks

- Smaller computers could be linked together, or networked, to share memory space, software, information and to communicate with each other.
- The LAN (Local Area Network) directly wired computers together.
- Modems (modulators-demodulators) allowed computers to communicate with each other over telephone lines.

ARPANET

- The U.S. Defense Department expanded one of its Local Area Networks to include computers at many locations, connected by telephone lines.
  - This was called the Advanced Research Projects Agency Network, or ARPANET.
- In the 1980s, ARPANET was expanded to connect universities, research institutions, and government agencies around the world.
The Internet

- The Internet, or World Wide Web, is a further expansion of ARPANET.
- Internet connections are widely available in the industrialized countries and are accessed by cable, high speed phone connections, wireless connections, as well as ordinary dial-up.

The Internet transformation

- The Internet has transformed the dissemination of information in a very short time.
- Information on almost any subject whatsoever is available on the Internet.
- Some institutions, e.g. York University, rely on the Internet for most of their business transactions and communication.

Spam, hackers, and other evils

- Email has become the medium of choice for sending messages rapidly to the next desk or around the world.
  - However, the ease of using email has attracted unwanted messages, spam, that clog In boxes.
- Sensitive information is posted and financial transactions are completed on the Internet with a great increase in productivity and efficiency.
  - But hackers find ways into protected sites and can wreak major havoc anonymously.
The Computer Revolution?

- The Computer/Internet Age has begun too recently for us to assess its impact on society.
- It seems destined to bring about a total and major change in human life rivaling the Agricultural and Industrial Revolutions.