

SI100B
Introduction to Information
Science and Technology
(Electrical Engineering)

Lecture #1 Introduction

Instructor: Junrui Liang (梁俊睿)
Sept. 16th, 2021

Instructors

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 - Research fields:
 - Self-powered Internet of Things (自供能物联网)
 - Power electronics & power management IC (电力电子与功率管理芯片)



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Siyu Jin
靳思宇



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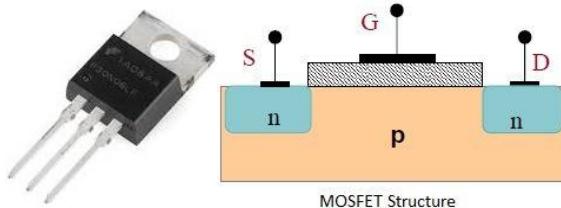
硕士生

本科生

Logistics

- Teaching goal in seven lectures

Device (1 lecture)



Circuit (4 lectures)



System (1 lecture)

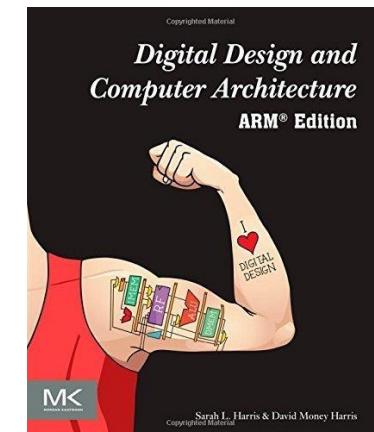
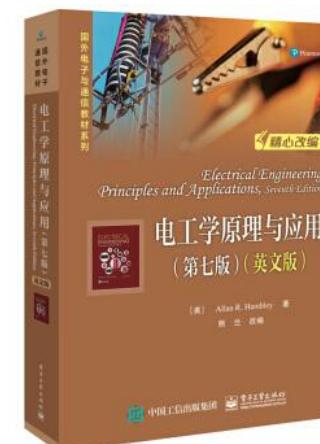


- Reference books

- Allan R. Hambley, *Electrical Engineering Principles and Applications* (6th ed.), Prentice-Hall (Pearson Education), 2013.
- Sarah Harris, David Harris, *Digital Design and Computer Architecture. ARM Edition*, Morgan Kaufmann, 2015.

- Grading (20% of the course)

- One survey/quiz in each 45 min lecture ($0.5\% \times 14 = 7\%$)
- One homework assignment in each two weeks ($3\% \times 3 + 4\% = 13\%$)



(Pictures are from the Internet)

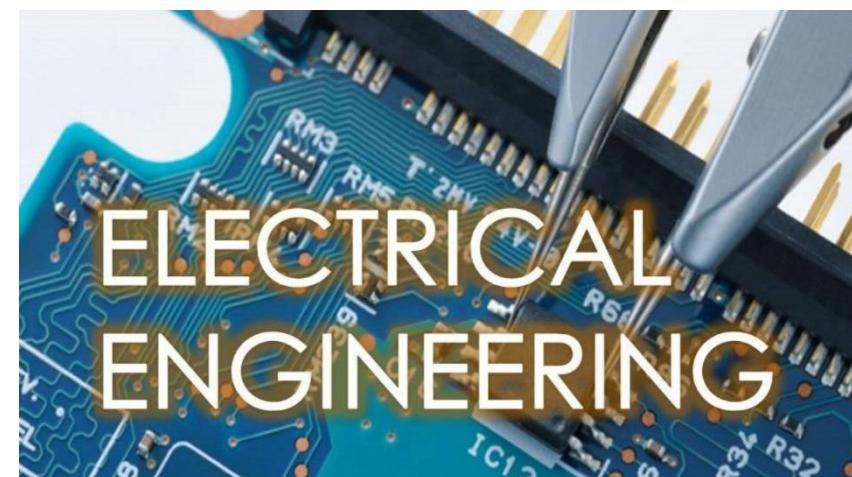
Study Purpose of the EL Part

- 哲学 (bao'an) 三问
 - Who are you?
 - Where are you from?
 - Where are you going?
- In this part, we ask
 - What is EE?
 - Where is EE from?
 - Where is EE going?

To answer those questions
throughout your life



To answer these questions
in seven lectures



(Pictures are from the Internet)

Independent Study

| High-school style 中学模式 | University style 大学模式 |
|---------------------------|----------------------------|
| Specific space (固定教室) | Open environment (开放式环境) |
| A few subjects (科目少) | Many subjects (许多科目) |
| Repeating contents (反复复习) | Few recitation (极少重复) |
| Monotonous media (媒介单一) | Multi-media (多种媒介) |
| Learning for exams (在考中学) | Learning by doing (尝试在做中学) |
| Single purpose (高考独木桥) | Diversity (出路差异化) |
| 知识改变命运 | 见识决定宽度, 能力决定高度 |



(Pictures are from the Internet)

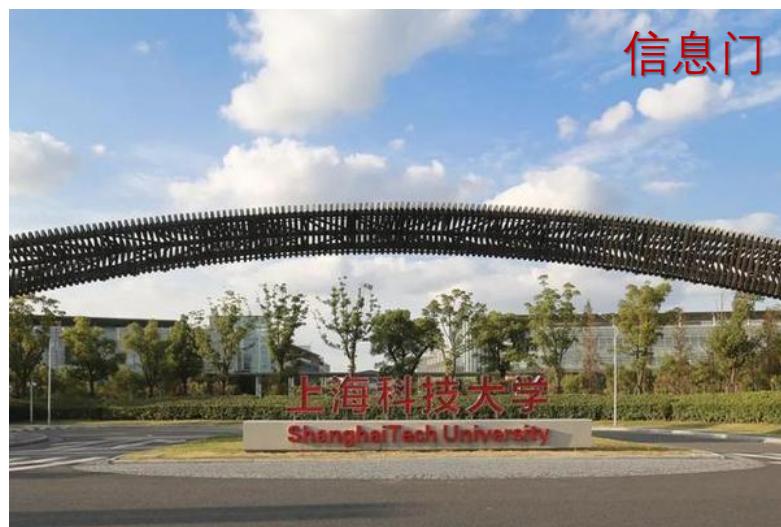
Lecture Outline

1. Prologue: information science and technology
2. What "electrical" stands for?
3. What "engineering" stands for?
4. Relation between information & electricity
5. Milestone technologies towards the information era

----- (break) -----

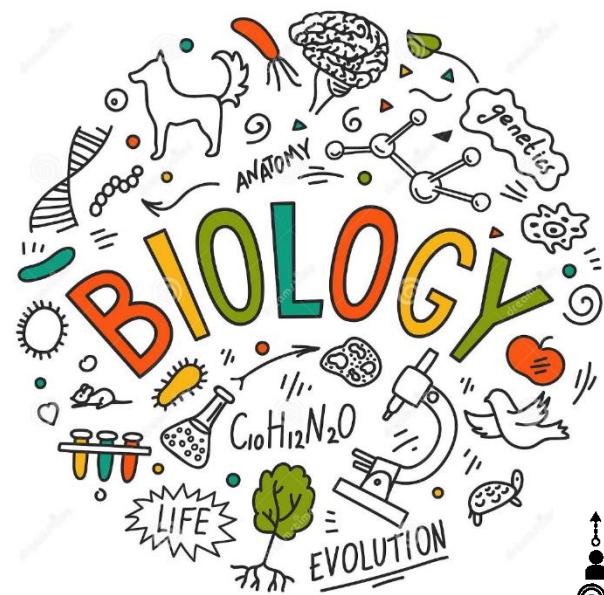
6. EE roadmap
7. Review: electricity in high-school physics
8. Some essential concepts
 - #1: dynamic system (动态系统)
 - #2: time domain & frequency domain (时域与频域)
 - #3: analog (continuous) & digital (discrete) (模拟和数字)
 - #4: linearity & nonlinearity (线性和非线性)

ShanghaiTech & SIST



SIST vs. SPST & SLST

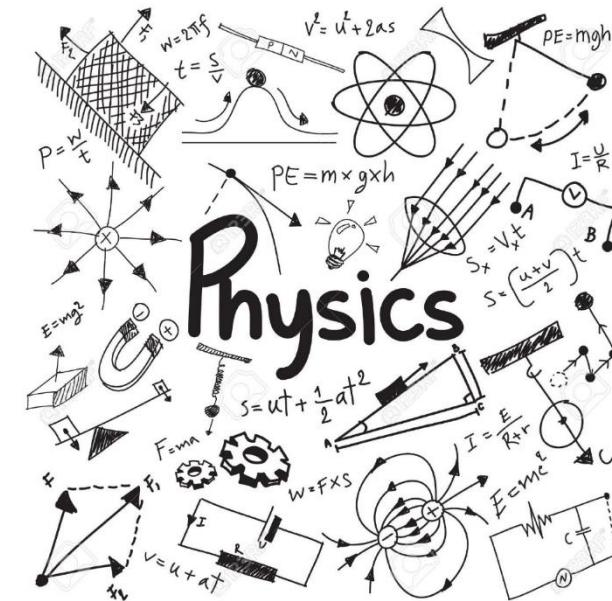
- SLST: 研究“活”的东西



- SIST:
研究“虚拟”的东西



- SPST: 研究“死”的东西



Needs more
imagination
and **creativity**

(Pictures are from the Internet)

Quiz #1

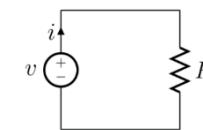
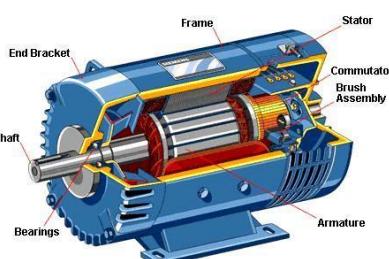
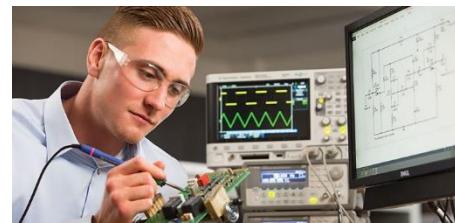
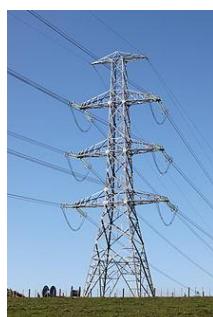
- Can you distinguish three similar terms

Electric

Electrical

Electronic

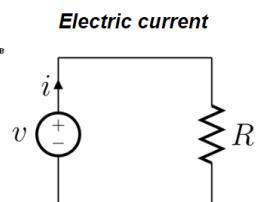
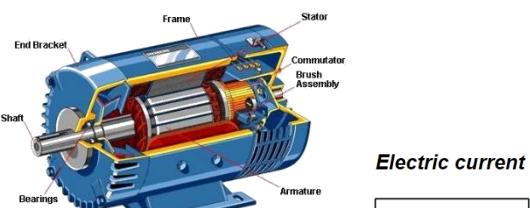
- Scan the QR code for the questionnaire



Answers

Electric

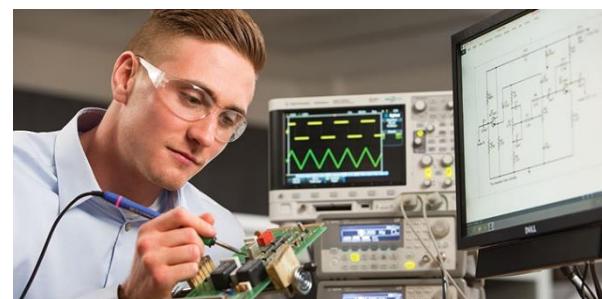
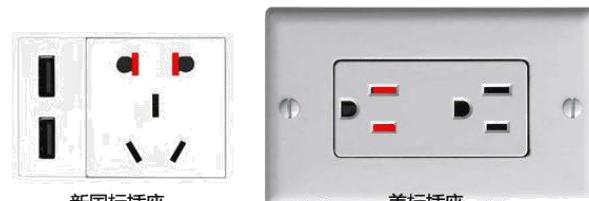
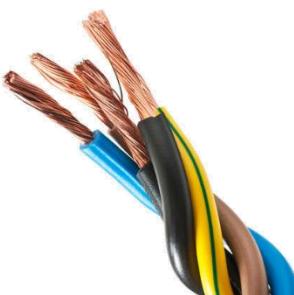
电力, 电能 (强调功率与能量)



(Pictures are from the Internet)

Electrical

电气 (强调物理特性)



Electronic

电子 (强调信息特性)



ENIAC (Electronic Numerical Integrator and Computer)



A modern way to process information & energy

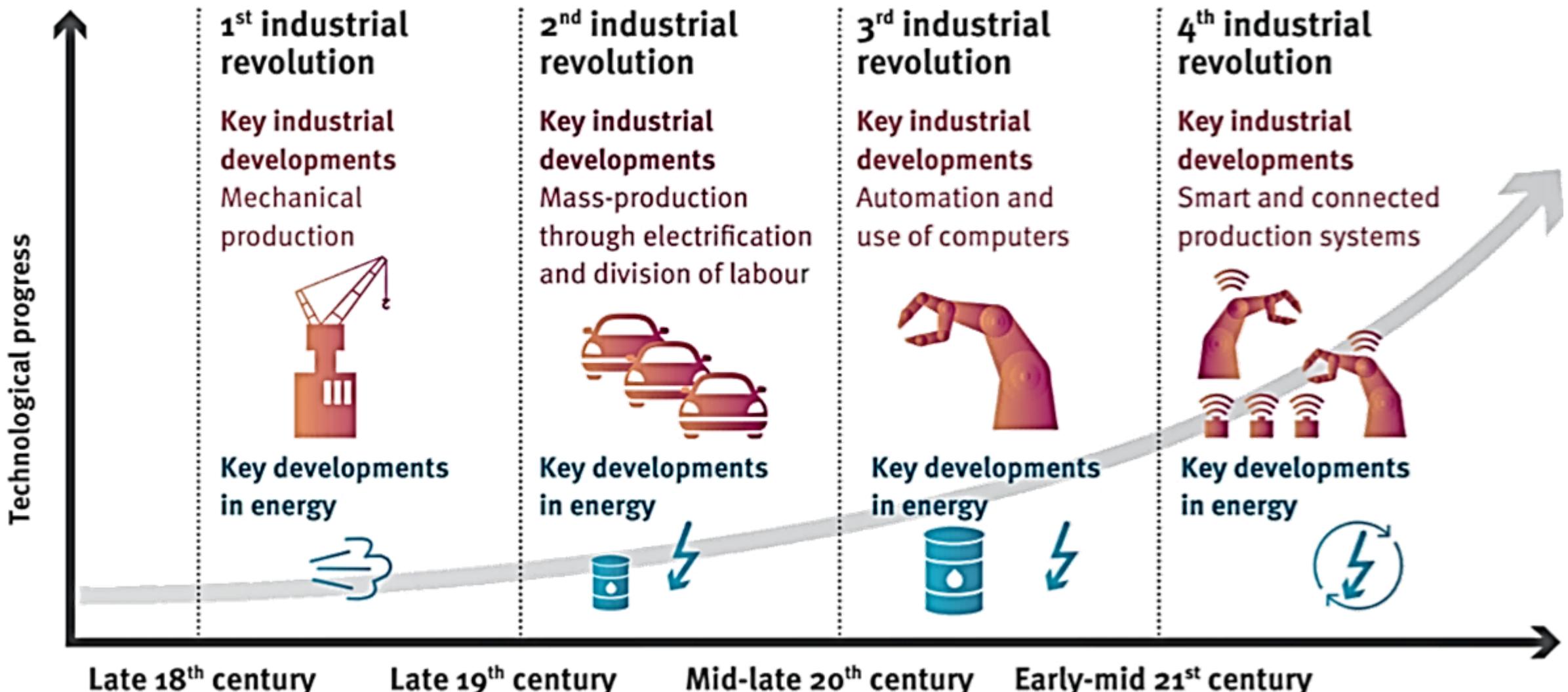
- Electrical engineering (电气工程、电机工程) design systems that have two main objectives:
 - To gather, store, process, transport, & present **information** (狭义EE)
 - To distribute, store, and convert **energy** between various forms



- In many electrical systems, the manipulation of energy and the manipulation of information are **interdependent**

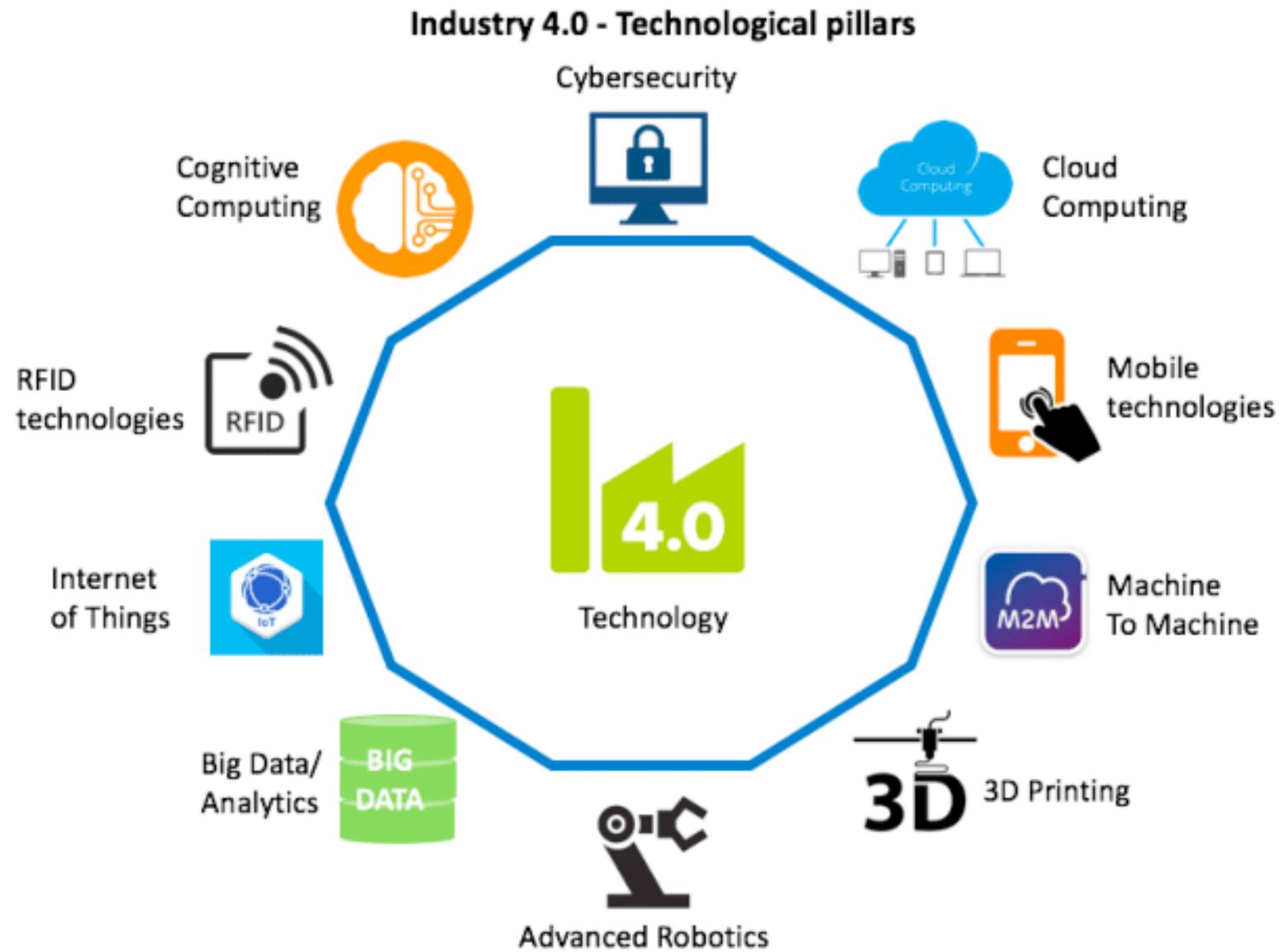
(Definition is from Hambley Ch1; Pictures are from the Internet)

Electrical engineering & industrial revolutions



(Accelerating clean energy through Industry 4.0, by Industrial Development Organization, United Nations, 2017)

Industry 4.0



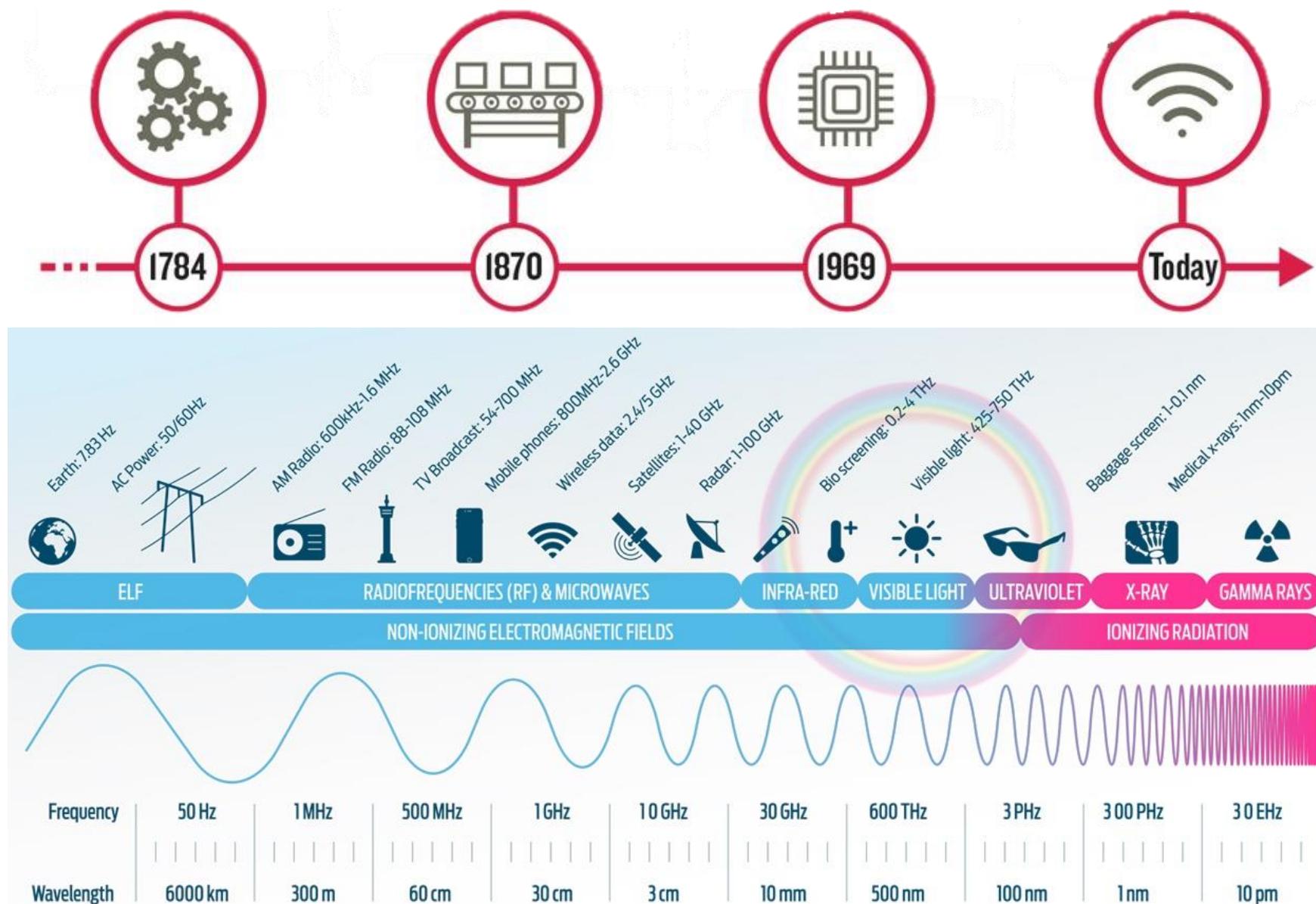
(Pictures are from the Internet)

Made in China 2025



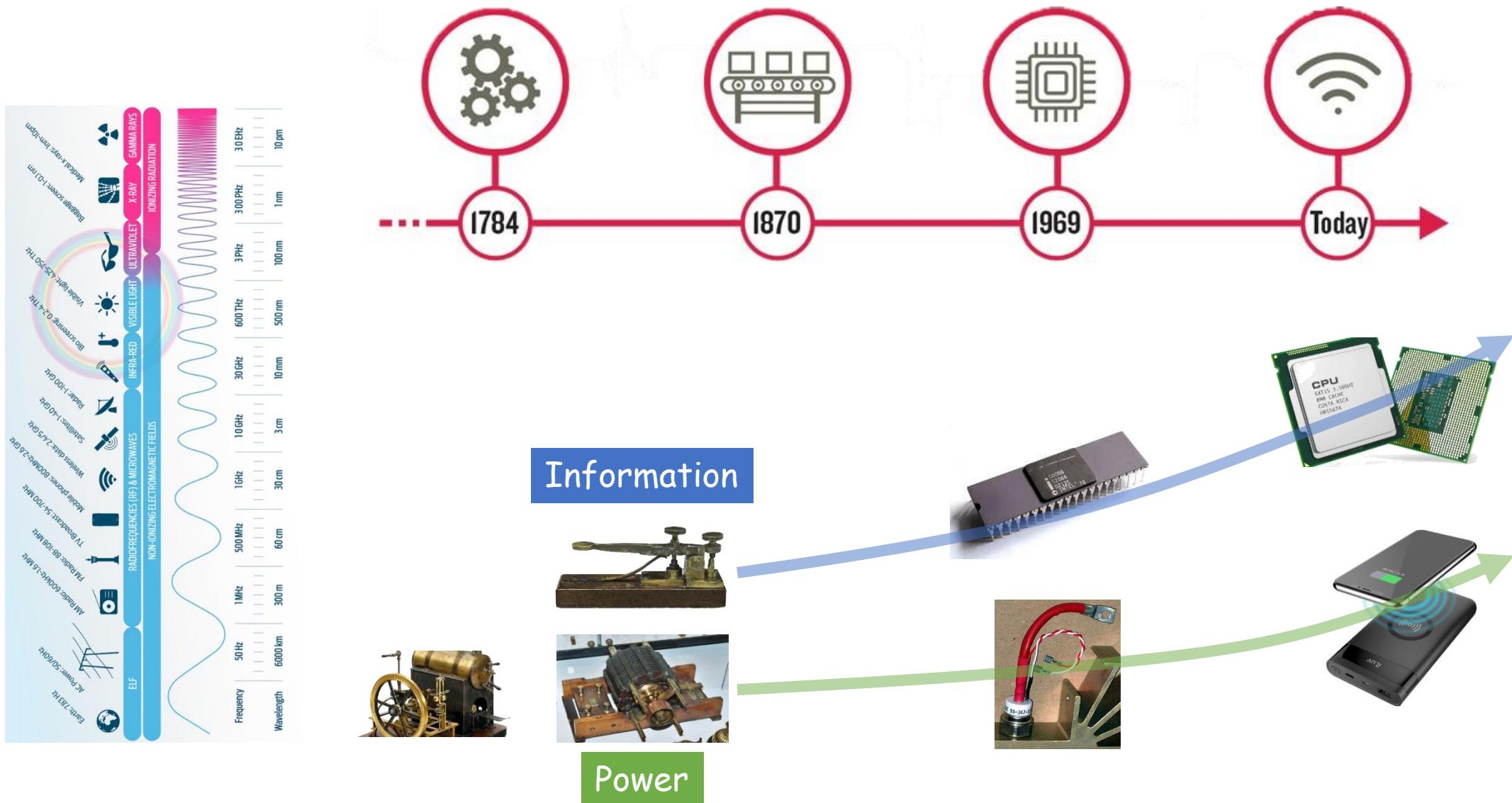
(<http://cn.brics-info.org>)

Industrial revolutions & frequency spectrum



(Pictures are from the Internet)

How fast power & information are processed



(Pictures are from the Internet)

Subdivisions of electrical engineering

• Communication systems

(通信系统)

- Transport information
(eq. to human nervous system)



传输信息

• Computer systems (计算系统)

- Process and store information (eq. to human brain)

处理信息



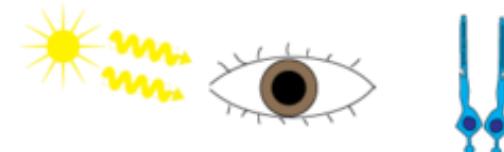
• Control systems (控制系统)

- Gather information with sensors (eq. to five senses)
- Control a physical process according to some information (eq. voice, arms & legs)



获取信息

执行信息

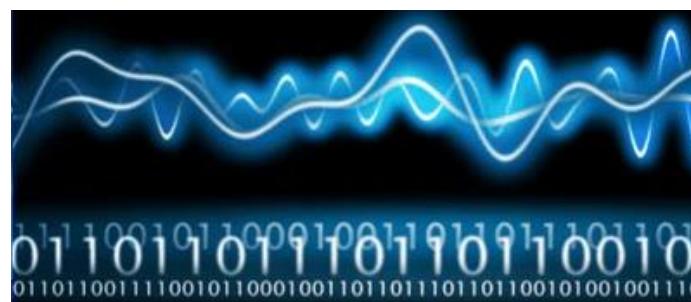
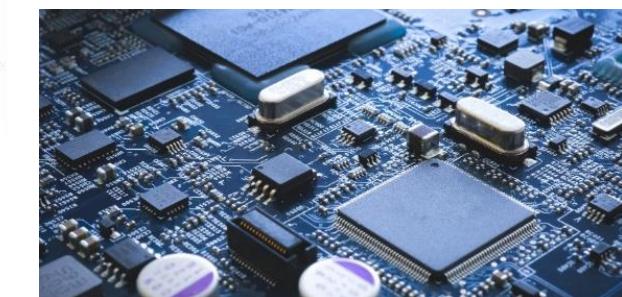
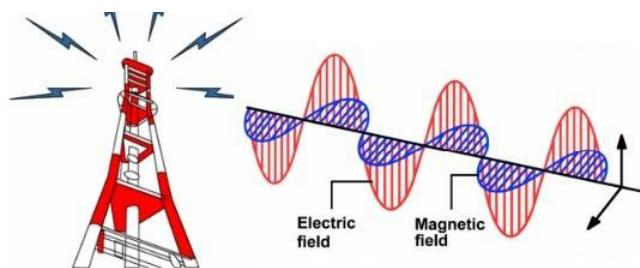


Signal → Collection → Transduction → Processing → Action

(Pictures are from the Internet)

Subdivisions of electrical engineering (cont'd)

- **Electromagnetics** (电磁学)
 - Wireless communication
 - Some functional treatments
- **Electronics** (电子学)
 - Materials, devices, and circuits used in amplifying and switching electrical signals
- **Photonics** (光子学)
 - Manipulating photons to replace the functions of manipulating electrons
- **Power systems** (电力系统)
 - Generation, transmission, distribution, and utilization of electrical energy
- **Signal processing** (信号处理)
 - to extract useful information from (electrical) signals

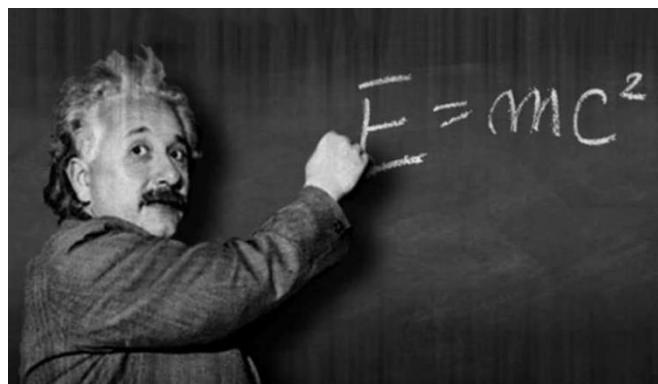
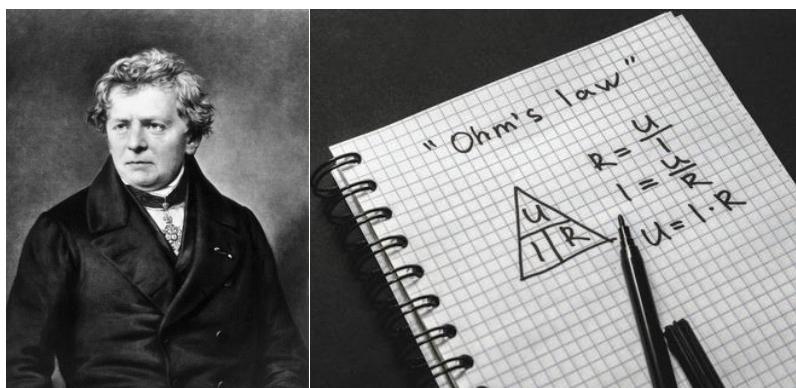


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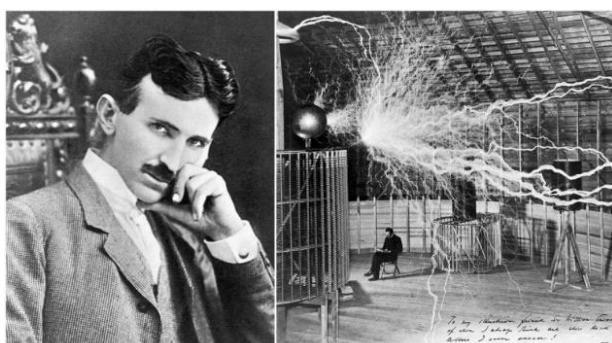
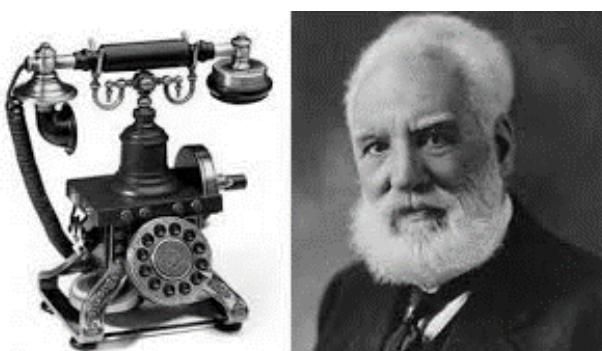
What “engineering” stands for?

- Engineering is the use of **scientific principles** to **design** and **build** machines, structures, and other items, including bridges, tunnels, roads, vehicles, and buildings.

Scientists 科学家



Engineers 工程师



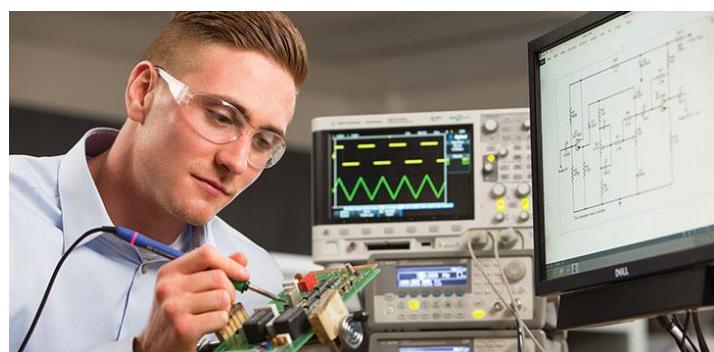
(<https://en.wikipedia.org/wiki/Engineering>)

(<https://interestingengineering.com/the-20-greatest-engineers-of-all-time>)

Engineering branches

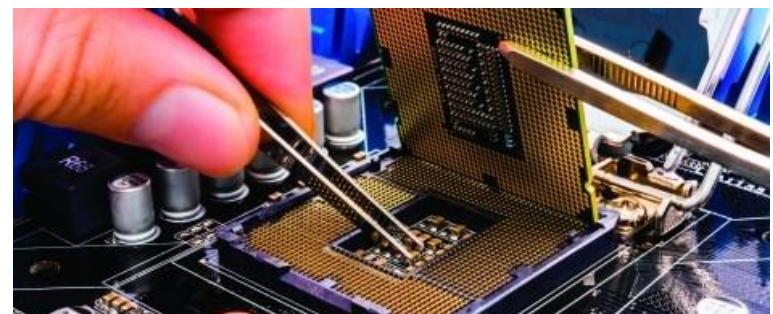
- Main branches

- Civil engineering 土木工程
- Mechanical engineering 机械工程
- Electrical engineering 电气工程
- Chemical engineering 化学工程



- Interdisciplinary

- Information engineering 信息工程
- Computer engineering 计算机工程
- Software engineering 软件工程
- Biomedical engineering 生物医学工程
- Aerospace engineering 航空工程
- ...



- **Computer science (CS)** is the study of algorithmic processes and computational machines.
- **Computer engineering (CE)** is a branch of engineering that integrates several fields of computer science and electronic engineering required to develop computer hardware and software.

(Pictures are from the Internet)

Information transfer 信息传输

Ancient



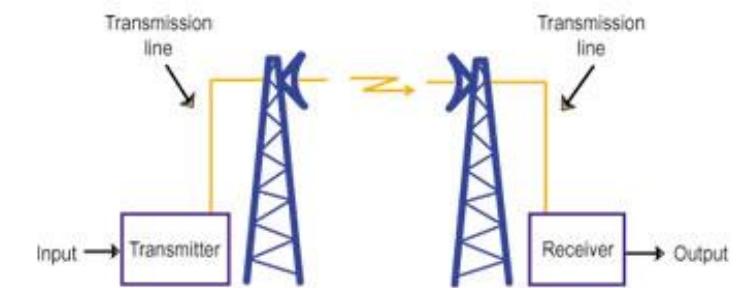
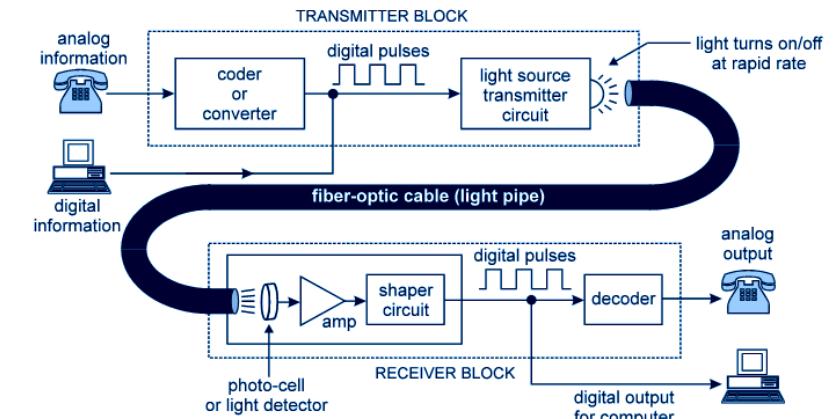
- Wired, short distance

- Wired, long distance

- Wireless, short/long distance

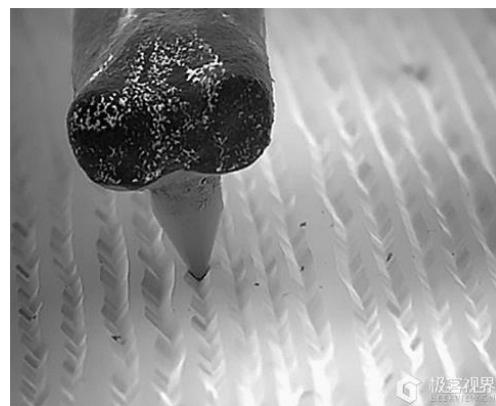
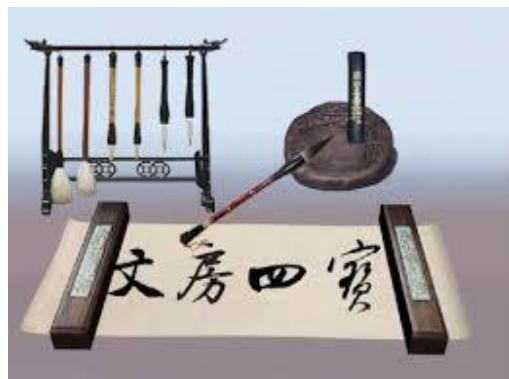
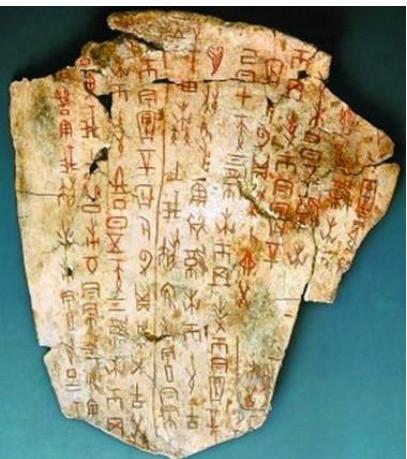
(Pictures are from the Internet)

Modern



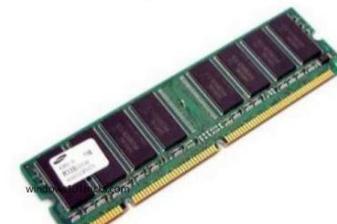
Information storage 信息存储

Ancient



RAM (Random Access Memory)

SRAM – Static RAM vs. DRAM – Dynamic RAM



HD



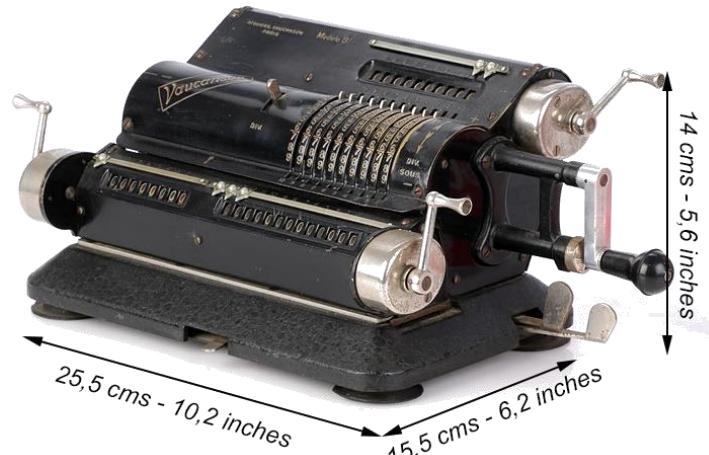
SSD

Modern

(Pictures are from the Internet)

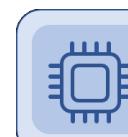
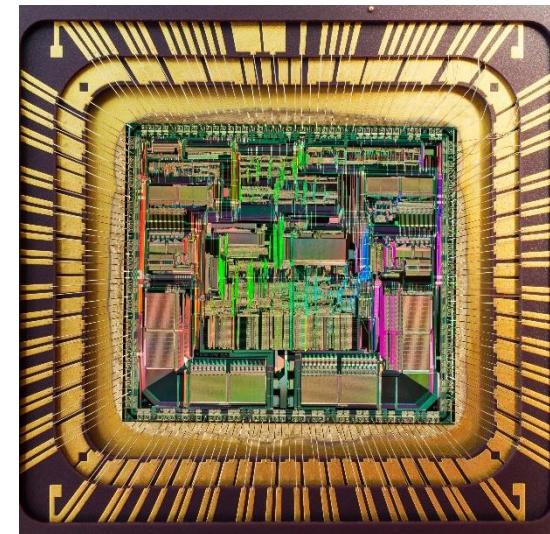
Information processing 信息处理

Ancient

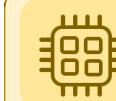


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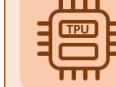
Modern

**CPU**

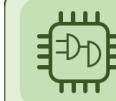
- Small models
- Small datasets
- Useful for design space exploration

**GPU**

- Medium-to-large models, datasets
- Image, video processing
- Application on CUDA or OpenCL

**TPU**

- Matrix computations
- Dense vector processing
- No custom TensorFlow operations

**FPGA**

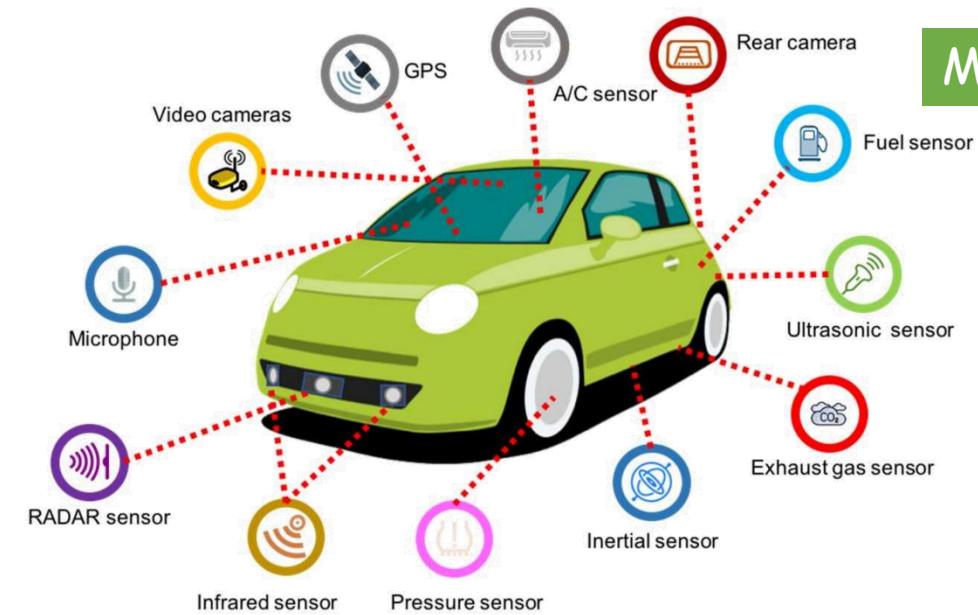
- Large datasets, models
- Compute intensive applications
- High performance, high perf./cost ratio

Information acquisition and execution 信息获取和执行

Ancient



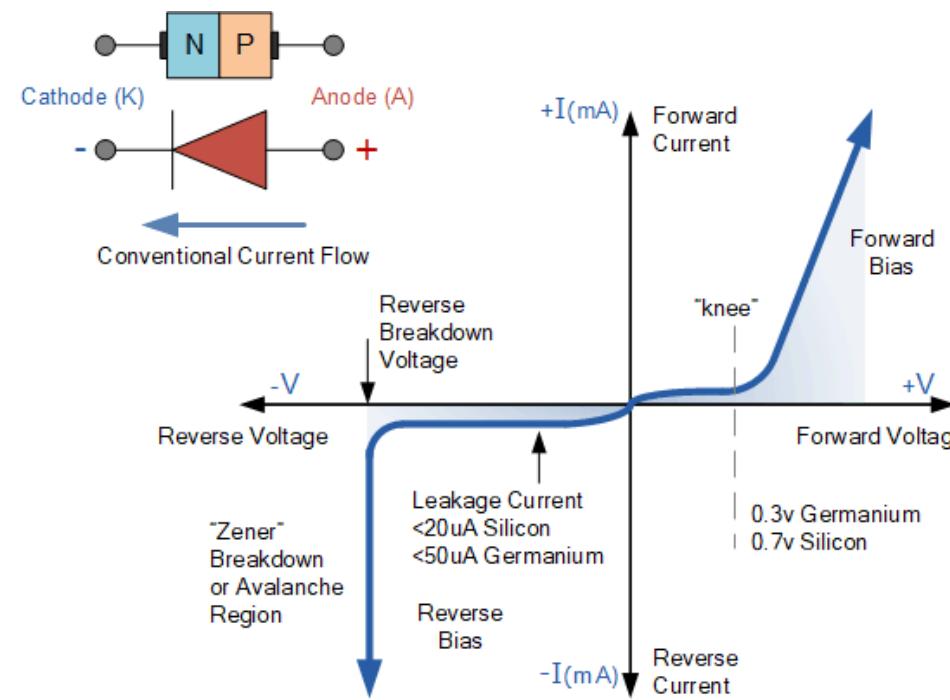
Modern



(Pictures are from the Internet)

Semiconductors and transistor effect 半导体和晶体管效应

- Solid-state devices

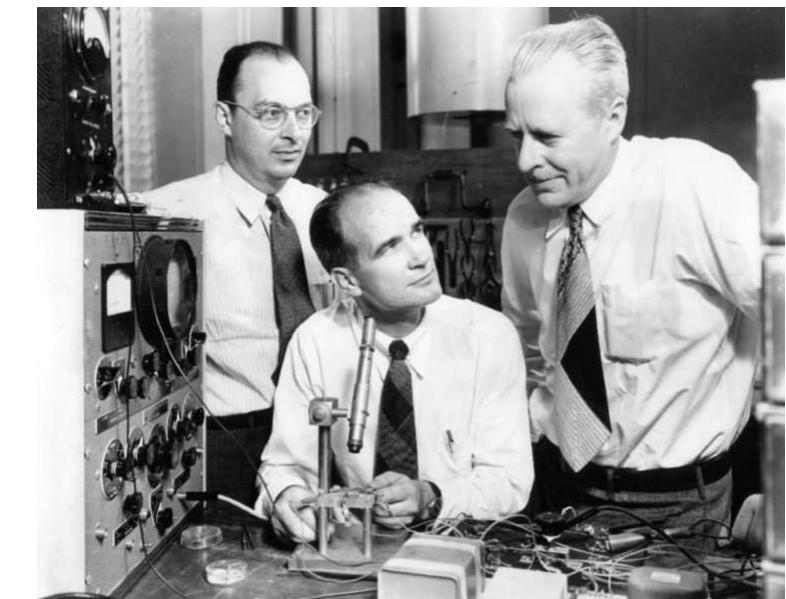


- Shockley diode equation

$$I = I_S \left[e^{\left(\frac{V_d}{nV_T} \right)} - 1 \right]$$

- William Shockley

- 1956 Nobel Prize in Physics with John Bardeen and Walter Brattain for "their researches on semiconductors and their discovery of the transistor effect"
- Developed at the Bell Labs



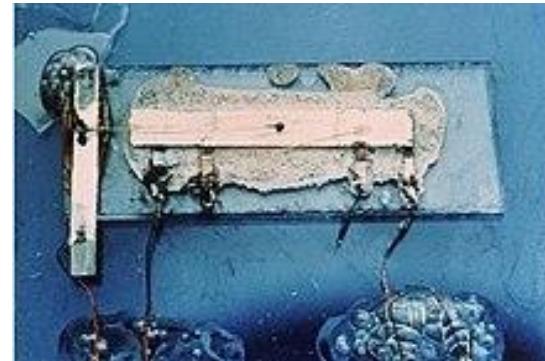
(Pictures are from the Internet)

Integrated circuit 集成电路 (芯片)

- Modern IC



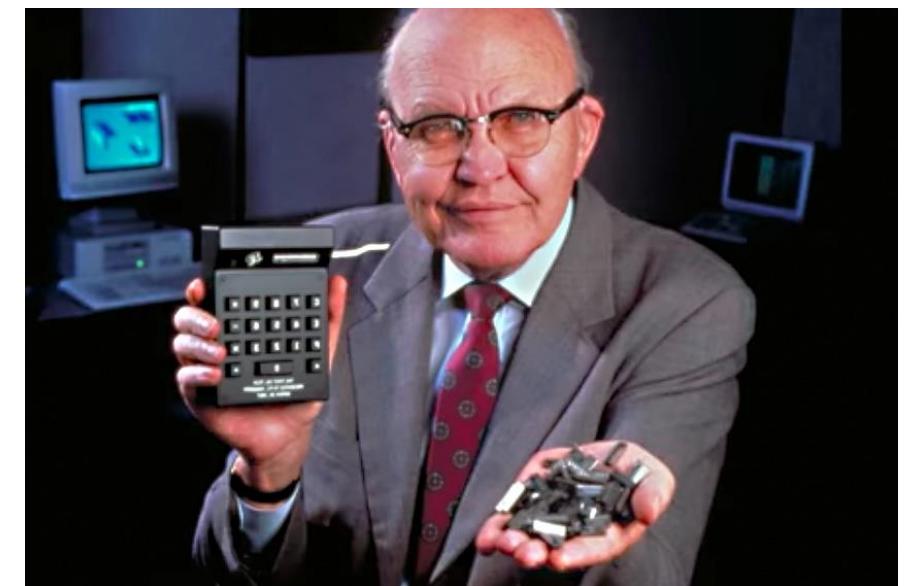
- The first IC on Germanium (1958)



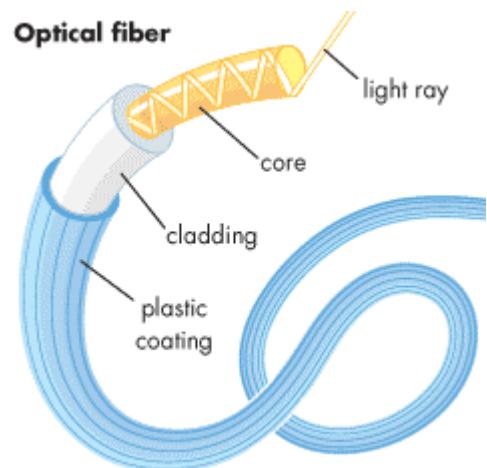
(Pictures are from the Internet)

- Jack St. Clair Kilby

- 2000 Nobel Prize in Physics for "his part in the invention of the integrated circuit"
- Developed at Texas Instruments Co.



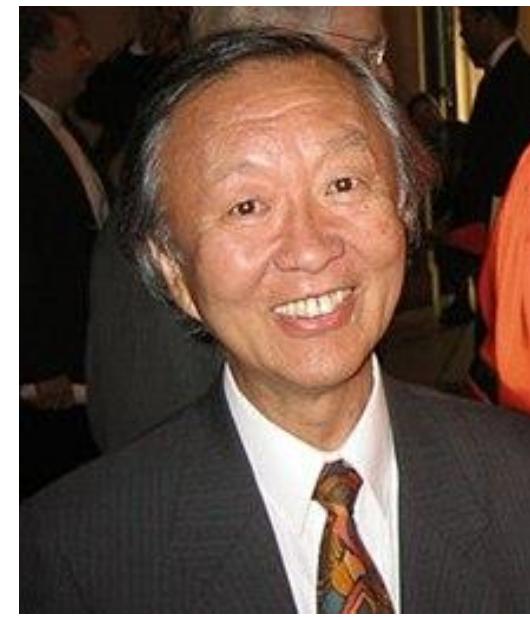
Optical fiber 光纤



Fiber vs. Copper

| | Fiber | Copper |
|---------------------|---|--|
| Bandwidth | 10-Gigabit and beyond | Gigabit |
| Future-proof | Evolving towards the desktop | CAT7 under development |
| Distance | 40 km+ @ 10,000 Mbps | 100 m @ 1000 Mbps |
| Noise | Immune | Susceptible to EMI/RFI interference crosstalk, and voltage surges |
| Security | Almost impossible to tap | Susceptible to tapping |
| Handling | Lightweight, thin diameter Strong pulling strength | Heavy, thicker diameter Strict pulling specifications |

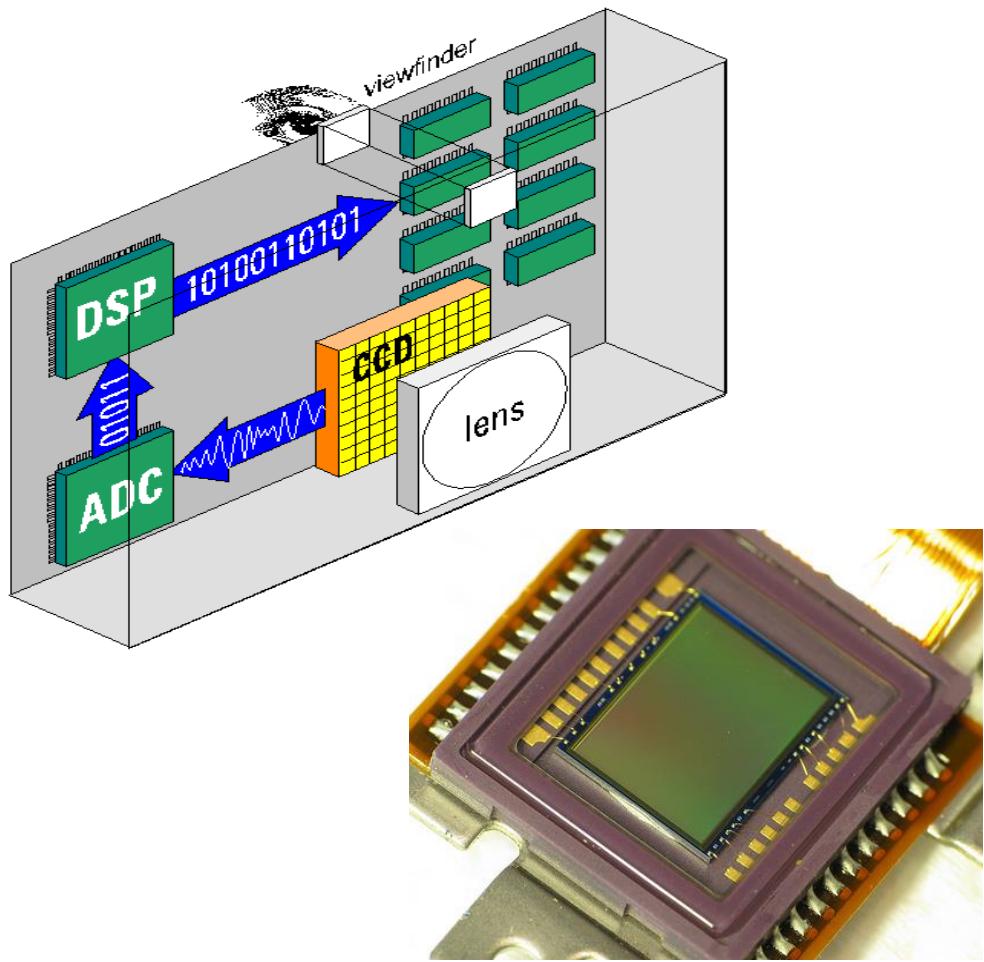
- Charles K. Kao 高锟
(Father of fiber optics)
 - 2009 Nobel Prize in Physics for "groundbreaking achievements concerning the transmission of light in fibers for optical communication"



(Pictures are from the Internet)

Charge-coupled device (CCD) 图像传感器

- CCD - image sensor



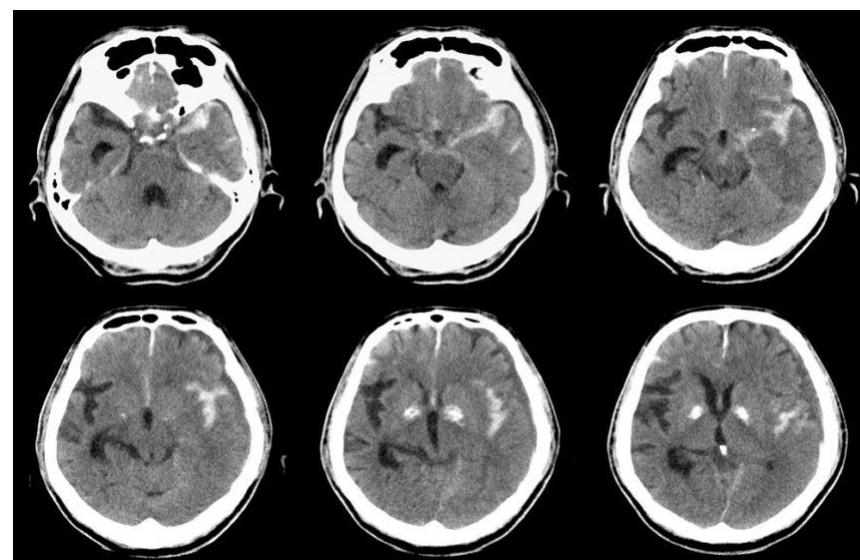
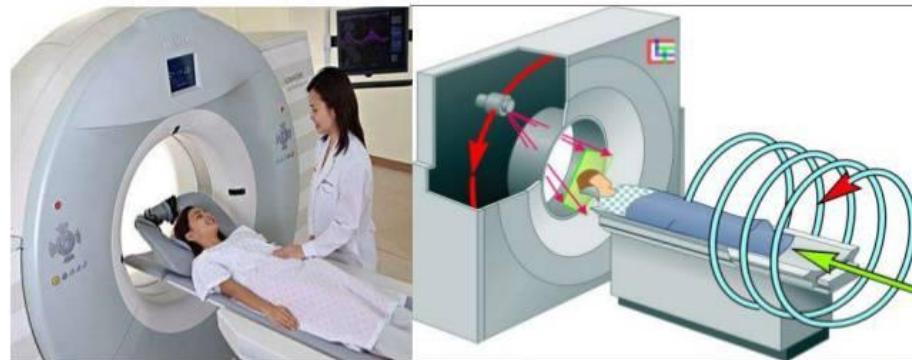
- Willard Boyle and George E. Smith
(Fathers of digital photography)
 - 2009 Nobel Prize in Physics for "their invention of the CCD concept"
 - Invented at the Bell Labs



(Pictures are from the Internet)

Computed tomography (CT) Scan 计算机断层扫描

Computed Tomography Scan

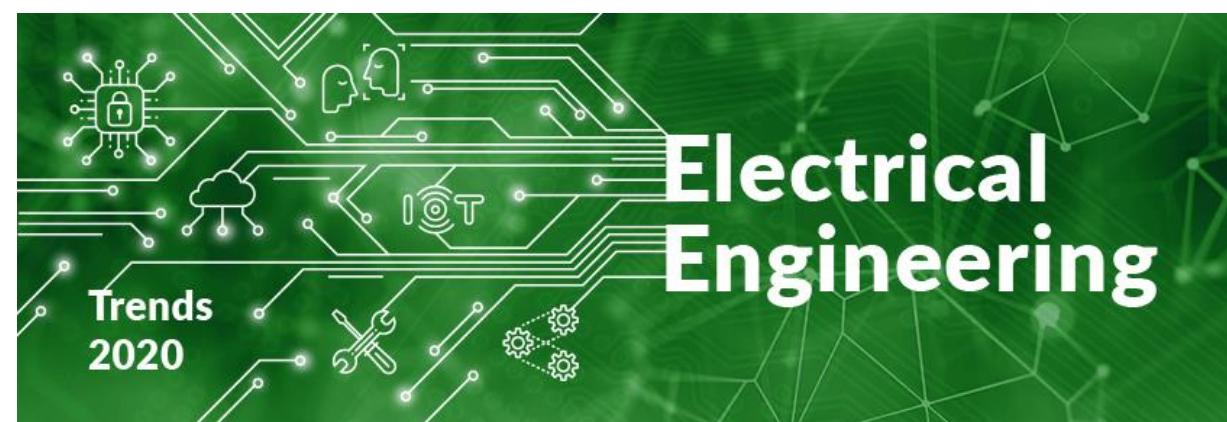


- The 1979 Nobel Prize in Physiology or Medicine was awarded jointly to South African American physicist **Allan M. Cormack** and British electrical engineer **Godfrey N. Hounsfield** "for the development of computer assisted tomography."

(Pictures are from the Internet)

The 13 Most Influential Trends To Watch In 2020

1. Smart grids
2. Electrical vehicles
3. Wireless power transfer
4. Wireless wearable tech
5. Artificial intelligence
6. Prefabricated products
7. Energy-saving lighting technologies
8. Automated client relationship and project management
9. The Internet of Things (IoT)
10. Increased use of drones
11. A boost in the implementation of sustainable energy
12. Energy storage and better batteries
13. Robotics

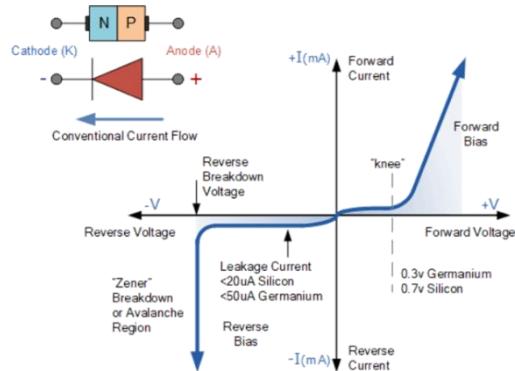


(<https://skelia.com/articles/electrical-engineering-the-13-most-influential-trends-to-watch-in-2020/>)

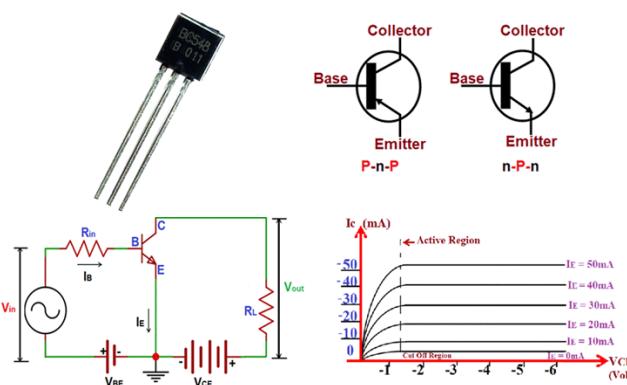
What you can learn from the EE curriculum?

- **Device physics**

- Diode 二极管



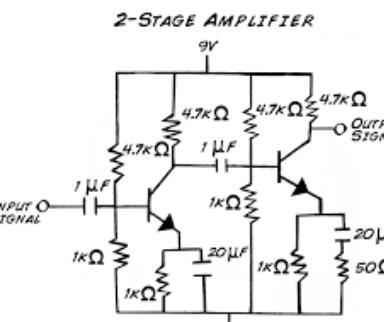
- Transistor 晶体管
(原意 trans-resistor)



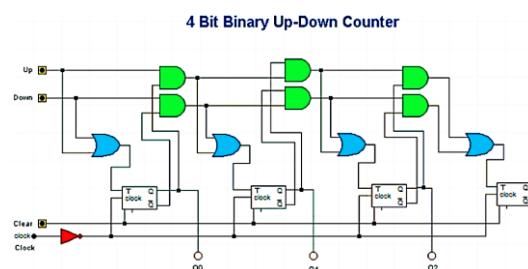
(Pictures are from the Internet)

- **Circuit /'sɜːrkɪt/ design**

- Analog



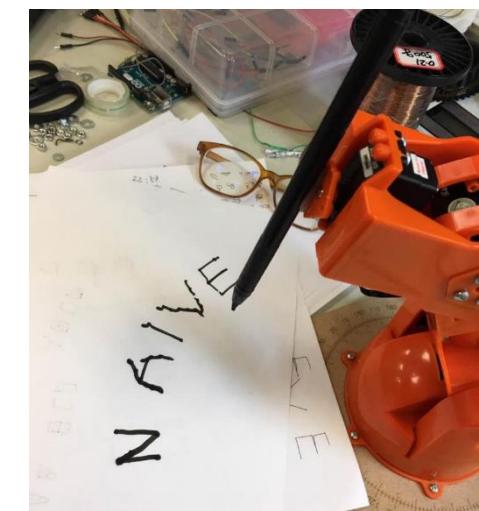
- Digital



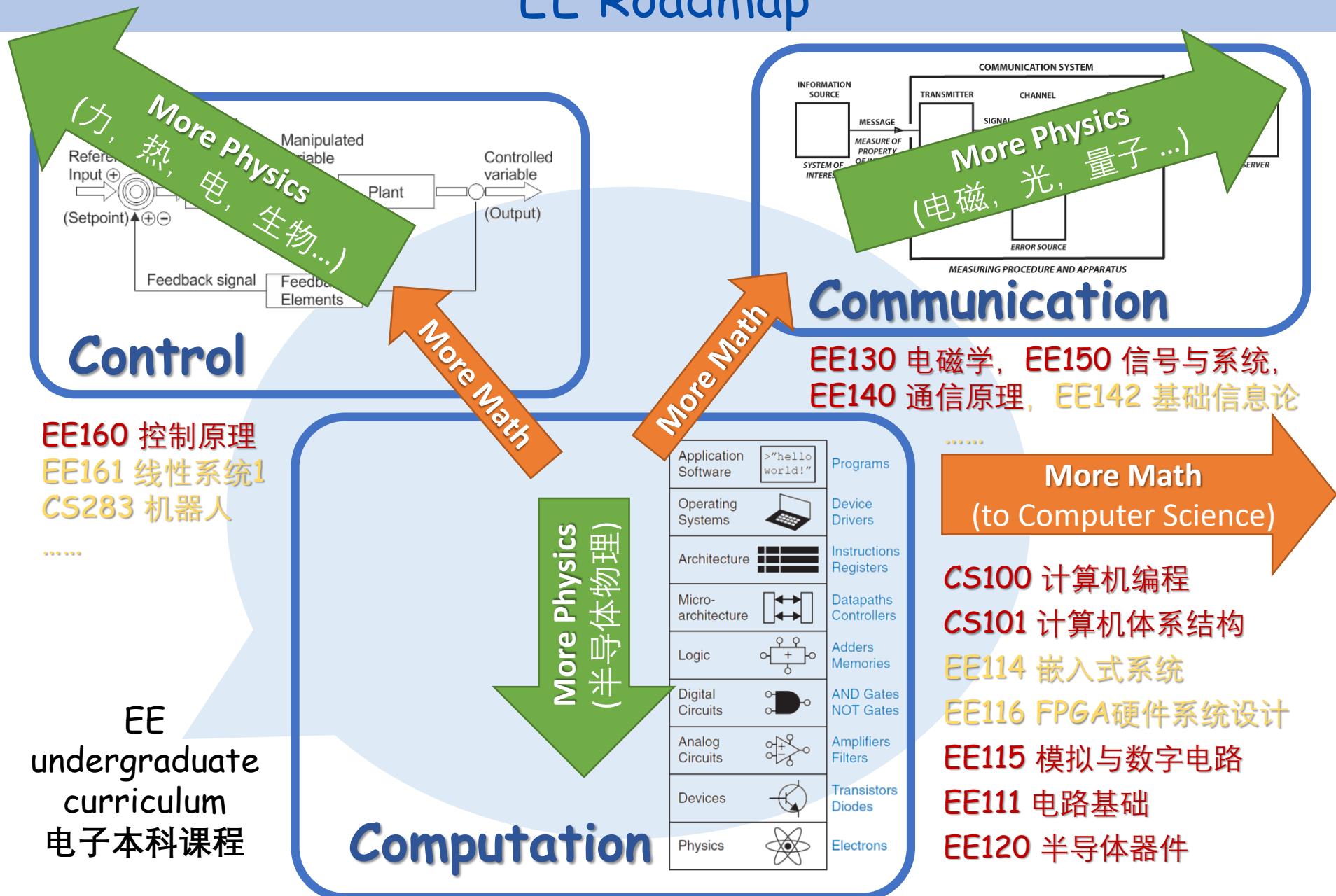
- Hands-on experience



- **System design**



EE Roadmap



电子信息工程专业本科生-专业选修课分类图

| Concentration | EE | | | CS | Math |
|--|--|--|---|--|---|
| | Physics & Device | Circuit | System | | |
| Information Engineering 信息 | 电磁学 | 电路基础 模拟与数字电路 | 信号与系统 控制原理 通信原理 数字信号处理 基础信息论 线性系统I 数字通信 信号检测与估值 网络信息论 线性系统II 网络编码理论 | 计算机编程 数据结构 算法基础 计算机网络 人工智能 计算机体系结构 操作系统 数据库和数据挖掘 算法设计与分析 算法博弈导论 深度学习 | 数学分析 线性代数 概率论与数理统计 离散数学 随机过程 优化与机器学习 矩阵分析 数值分析 复变函数与积分变换 (即目前开设的数学物理方法I) 偏微分方程数值解 |
| Control and Systems 控制 | 电磁学 | 电路基础 模拟与数字电路 嵌入式系统 | 信号与系统 控制原理 通信原理 线性系统I 数字信号处理 基础信息论 数字通信 | 计算机编程 算法与数据结构 算法基础 计算机网络 人工智能 I 计算机体系结构 I 并行计算 机器学习 深度学习 | 数学分析 线性代数 概率论与数理统计 优化与机器学习 复变函数与积分变换 (即目前开设的数学物理方法I) 矩阵分析 数值分析 偏微分方程 离散数学 凸优化 随机过程 应用代数几何 |
| Power & Energy 能源 | 半导体器件基础 电磁学 半导体器件物理 | 电路基础 模拟与数字电路 电力电子 嵌入式系统及课程设计 基于FPGA的硬件系统设计 可再生能源系统设计 模拟集成电路I | 信号与系统 控制原理 电力系统 数字信号处理 可再生能源系统 | 计算机编程 数据结构 计算机体系结构 人工智能 | 数学分析 线性代数 概率与数理统计 复变函数与积分变换 (即目前开设的数学物理方法I) 数值分析 优化与机器学习 |
| Microelectronics 微电子 | 半导体器件基础 电磁学 微纳加工与微机电系统基础 固体物理(物质) 量子力学(物质) 光电器件 半导体器件物理 微电子器件 微机电系统原理与设计 | 电路基础 模拟与数字电路 模拟集成电路I 数字集成电路I 射频电子学 数字信号处理 基于FPGA的硬件系统设计 数字信号处理的VLSI实现 无损检测与传感器技术选论 嵌入式系统及课程设计 | 信号与系统 控制原理及课程设计 通信原理 光通信系统 | 计算机编程 计算机体系结构 计算机网络 人工智能 数据结构 | 数学分析 线性代数 概率与数理统计 复变函数与积分变换 (即目前开设的数学物理方法I) 离散数学 偏微分方程 偏微分方程数值解 数值分析 随机过程 优化与机器学习 |
| Electromagnetic Waves & Optoelectronics 微波和光电子 | 电磁学及课程设计 半导体器件基础 物理光学 激光原理 微波工程I 光电器件 天线理论 | 电路基础 模拟与数字电路 射频电子学 导波光学 非线性光学(物质) 无损检测与传感器技术选论 | 信号与系统 通信原理 控制原理 光通信系统 数字信号处理 数字图像处理 | 计算机编程 算法基础 人工智能 计算机视觉 | 数学分析 线性代数 概率与数理统计 复变函数与积分变换 (即目前开设的数学物理方法I) 偏微分方程 偏微分方程数值解 随机过程 数值分析 优化与机器学习 |

Horizontal 广度

Vertical 深度

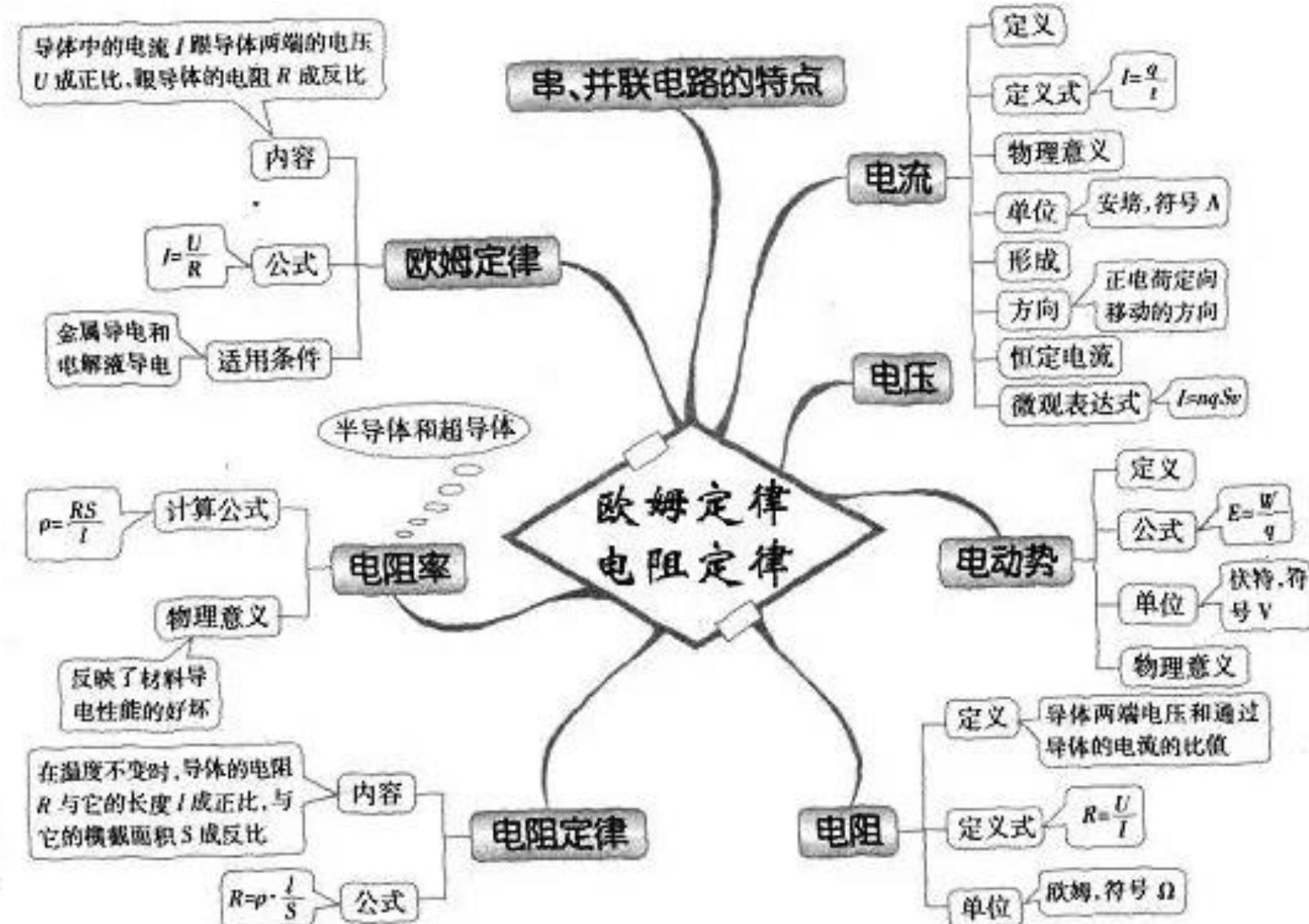
- **Compulsory courses**
必修课

- **Professional core courses**
专业核心课

- **Professional advanced courses**
专业进阶课

- **Consult your mentor from time to time!**

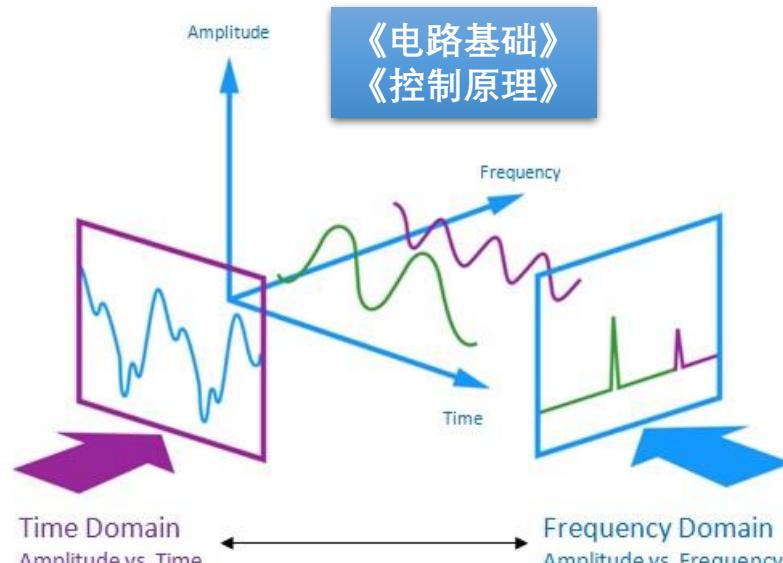
Electricity in high-school physics



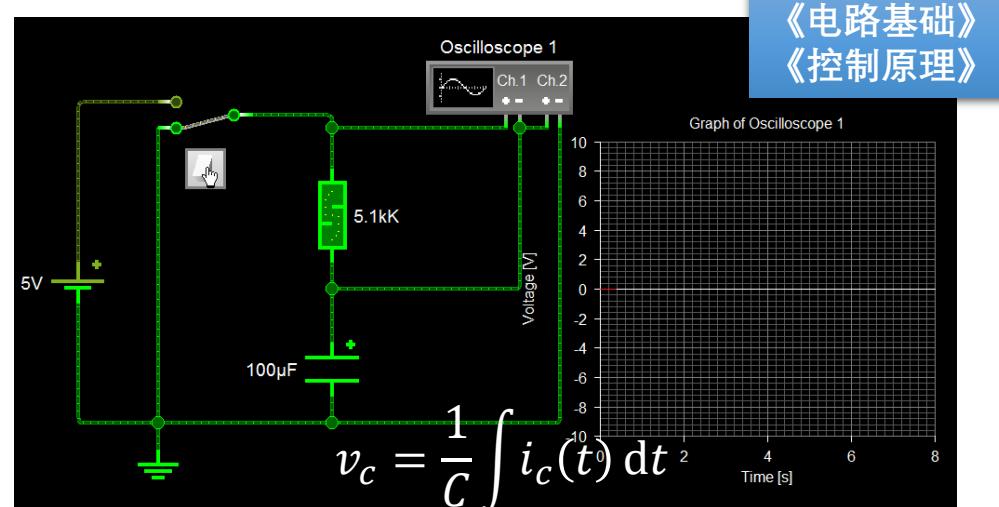
(Pictures are from the Internet)

Dynamic system 动态系统

- Opposite to static 静态 system
- Particle or ensemble of particles whose **state varies over time**
- Obeys **differential equations** involving time derivatives
- Physical (continuous) dynamics

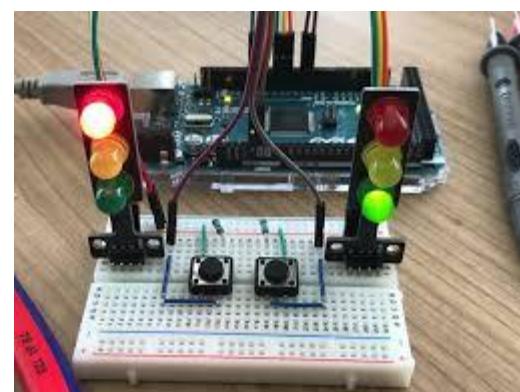


(Pictures are from the Internet)

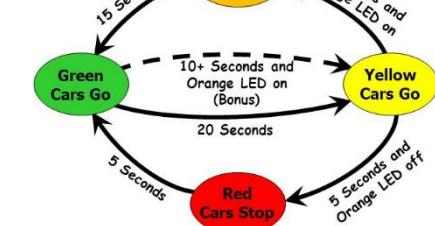


《电路基础》
《控制原理》

- Discrete dynamics



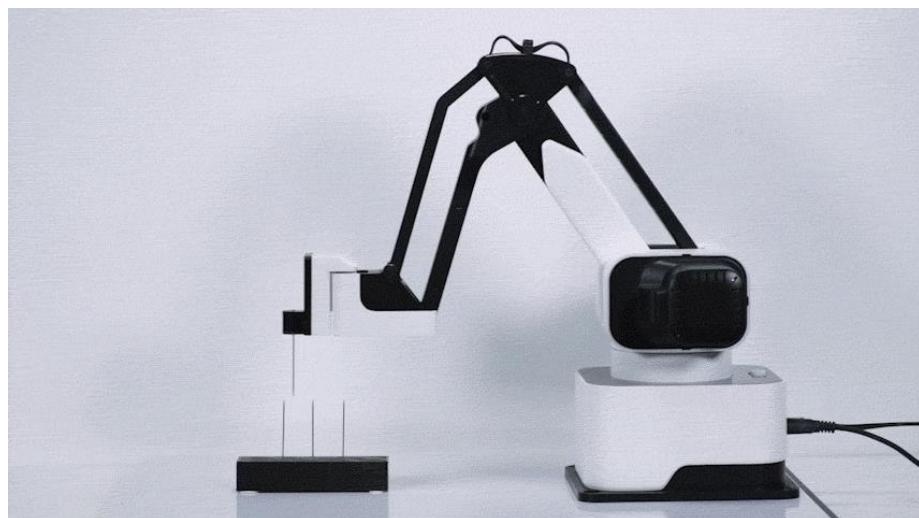
《数字电路》
《嵌入式系统》
《FPGA》



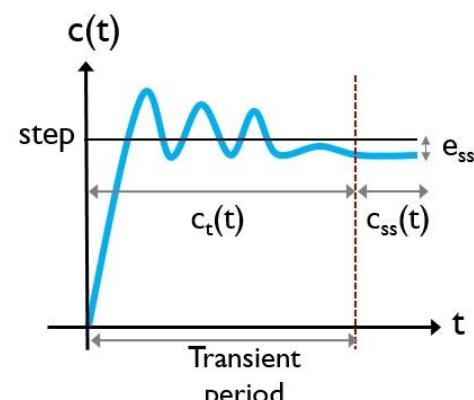
Time domain & frequency domain 时域与频域

- Why time-domain analysis?

We, human being moves over time.



Imaging to work with a chattering robot arm, any harmful effect?

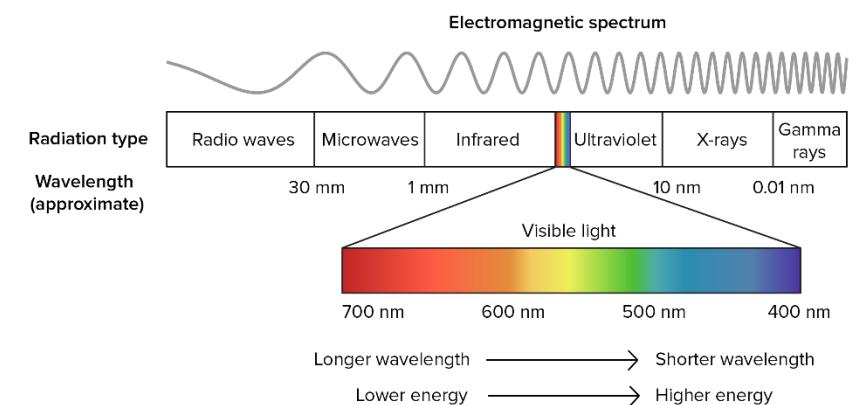


(Pictures are from the Internet)

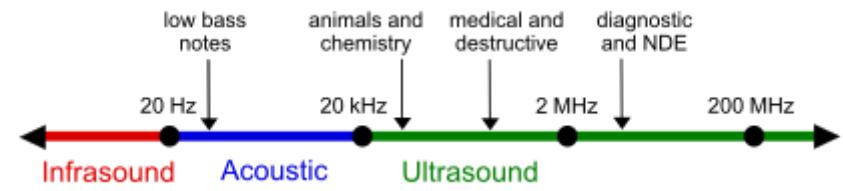
- Why frequency-domain analysis?

We, human being watch, listen, communicate over frequency.

EM wave



Sound wave



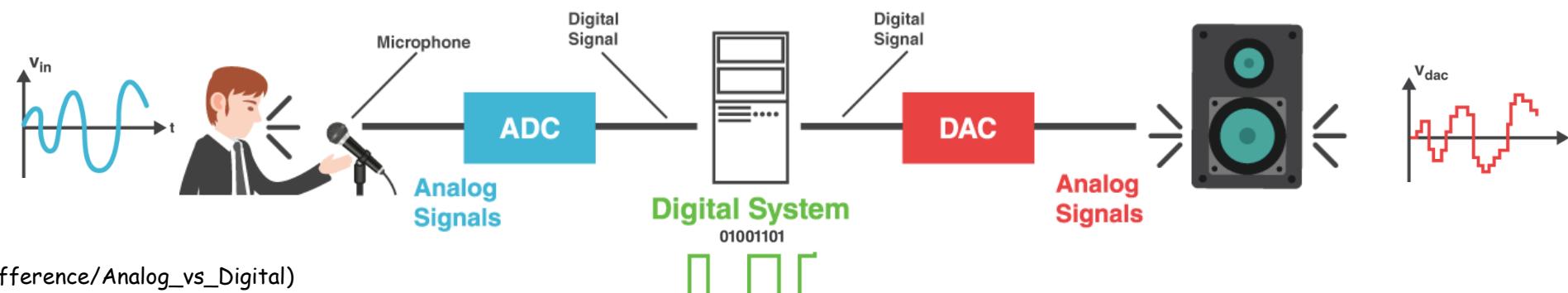
《电路基础》
《信号与系统》
《控制原理》

Analog & digital 模拟和数字

《模拟与数字电路》
《信号与系统》
《数字信号处理》



| | Analog | Digital |
|---------------------------|---|---|
| Signal | Analog signal is a continuous signal which represents physical measurements. | Digital signals are discrete time signals generated by digital modulation. |
| Waves | Denoted by sine waves | Denoted by square waves |
| Representation | Uses continuous range of values to represent information | Uses discrete or discontinuous values to represent information |
| Example | Human voice in air, analog electronic devices. | Computers, CDs, DVDs, and other digital electronic devices. |
| Technology | Analog technology records waveforms as they are . | Samples analog waveforms into a limited set of numbers and records them. |
| Data transmissions | Subjected to deterioration by noise during transmission and write/read cycle. | Can be noise-immune without deterioration during transmission and write/read cycle. |
| Response to Noise | More likely to get affected reducing accuracy | Less affected since noise response are analog in nature |
| Flexibility | Analog hardware is not flexible . | Digital hardware is flexible in implementation. |
| Applications | Thermometer | PCs, PDAs |
| Errors | Analog instruments usually have a scale which is cramped at lower end and give considerable observational errors . | Digital instruments are free from observational errors like parallax and approximation errors. |



(https://www.differenc.com/difference/Analog_vs_Digital)

Linearity & nonlinearity 线性和非线性

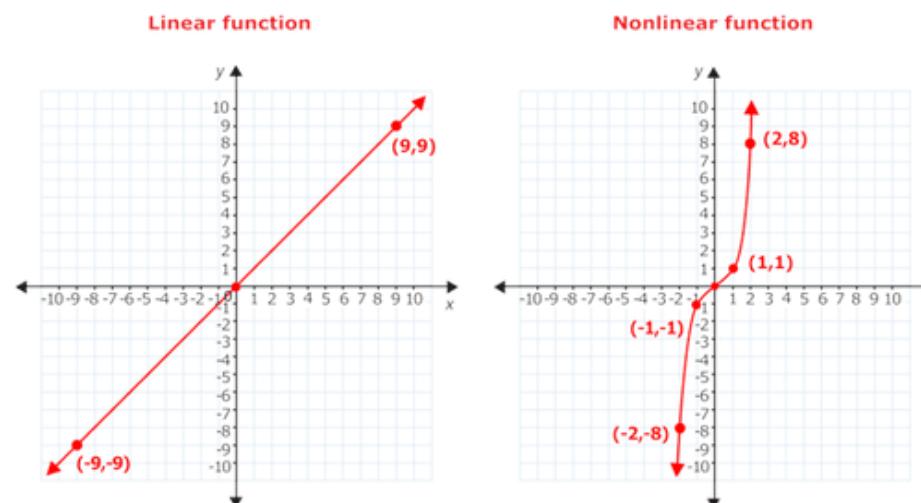
- In mathematics, a linear map or linear function $f(x)$ is a function that satisfies the two properties

- Additivity 可加性

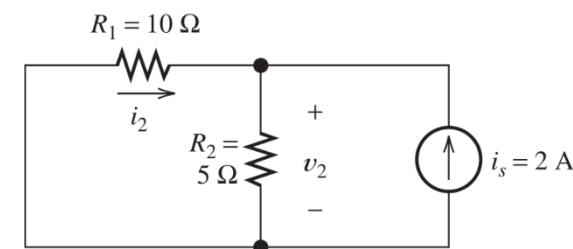
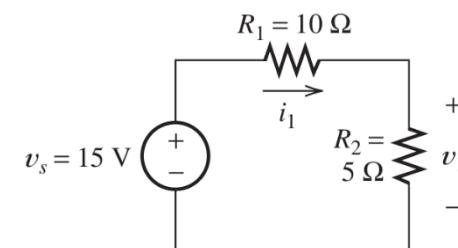
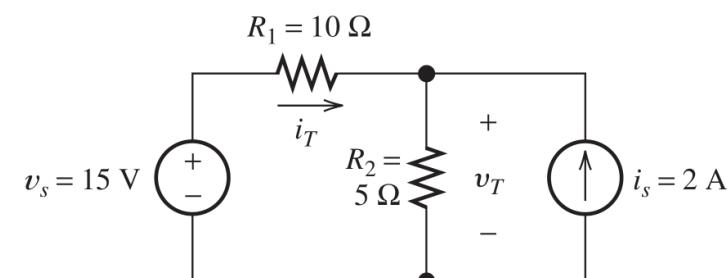
$$f(x + y) = f(x) + f(y)$$

- Homogeneity of degree 1 齐次性
 $f(\alpha x) = \alpha f(x)$ for all α

《信号与系统》
 《控制原理》
 《线性系统》



- Superposition 线性叠加

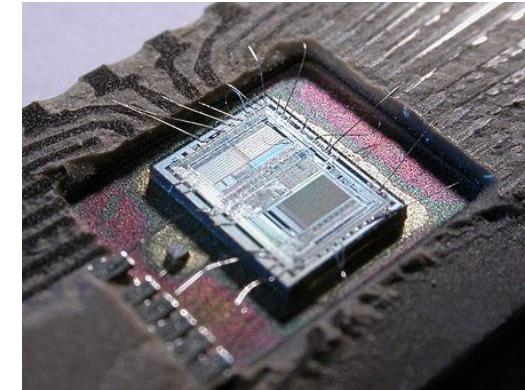
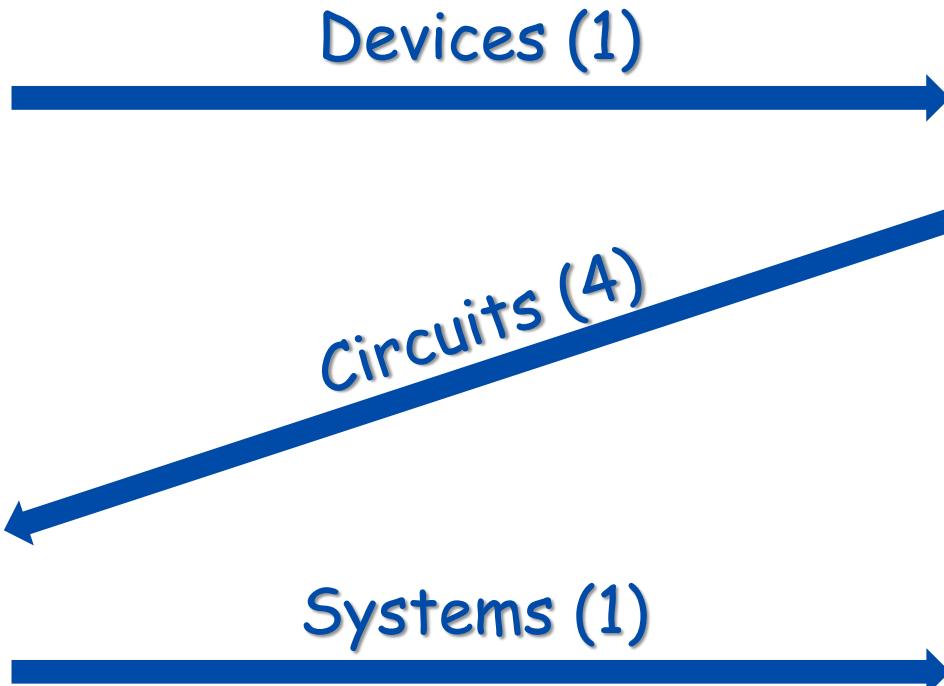


$$v_T = v_1 + v_2$$

Quiz #2

Contents of future lectures

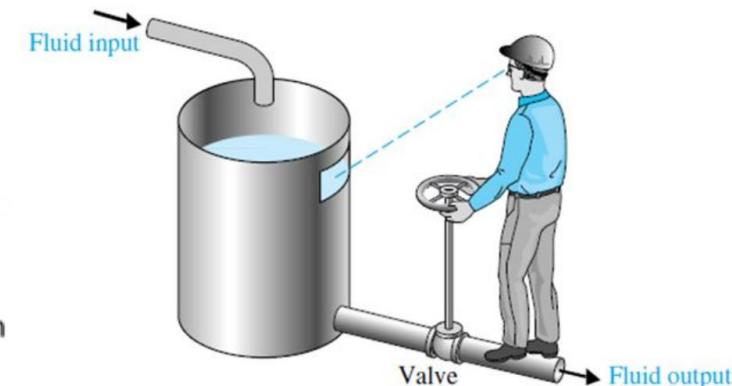
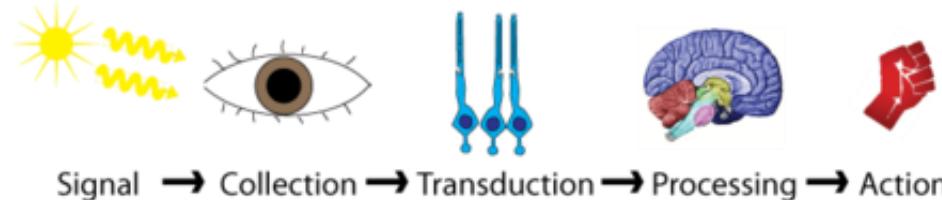
- The **theme story** of the following six lectures



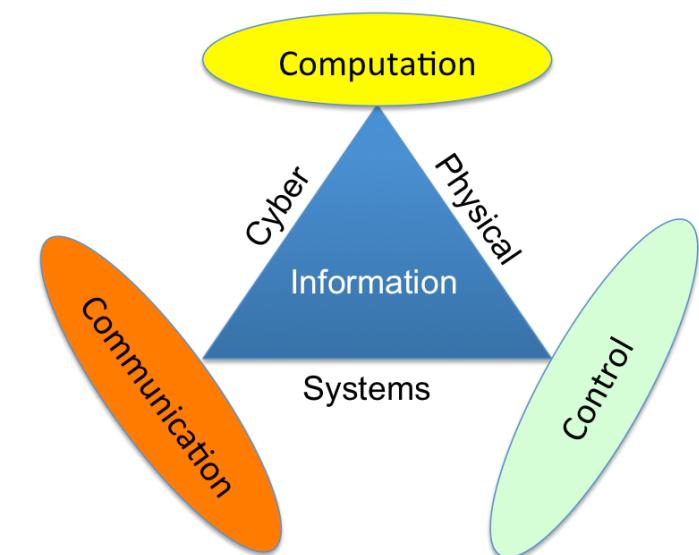
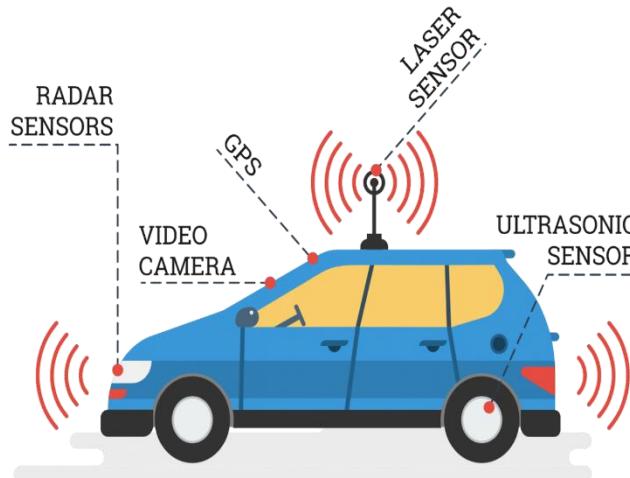
(Some pictures are from the Internet)

Contents of future lectures

- Manual control system



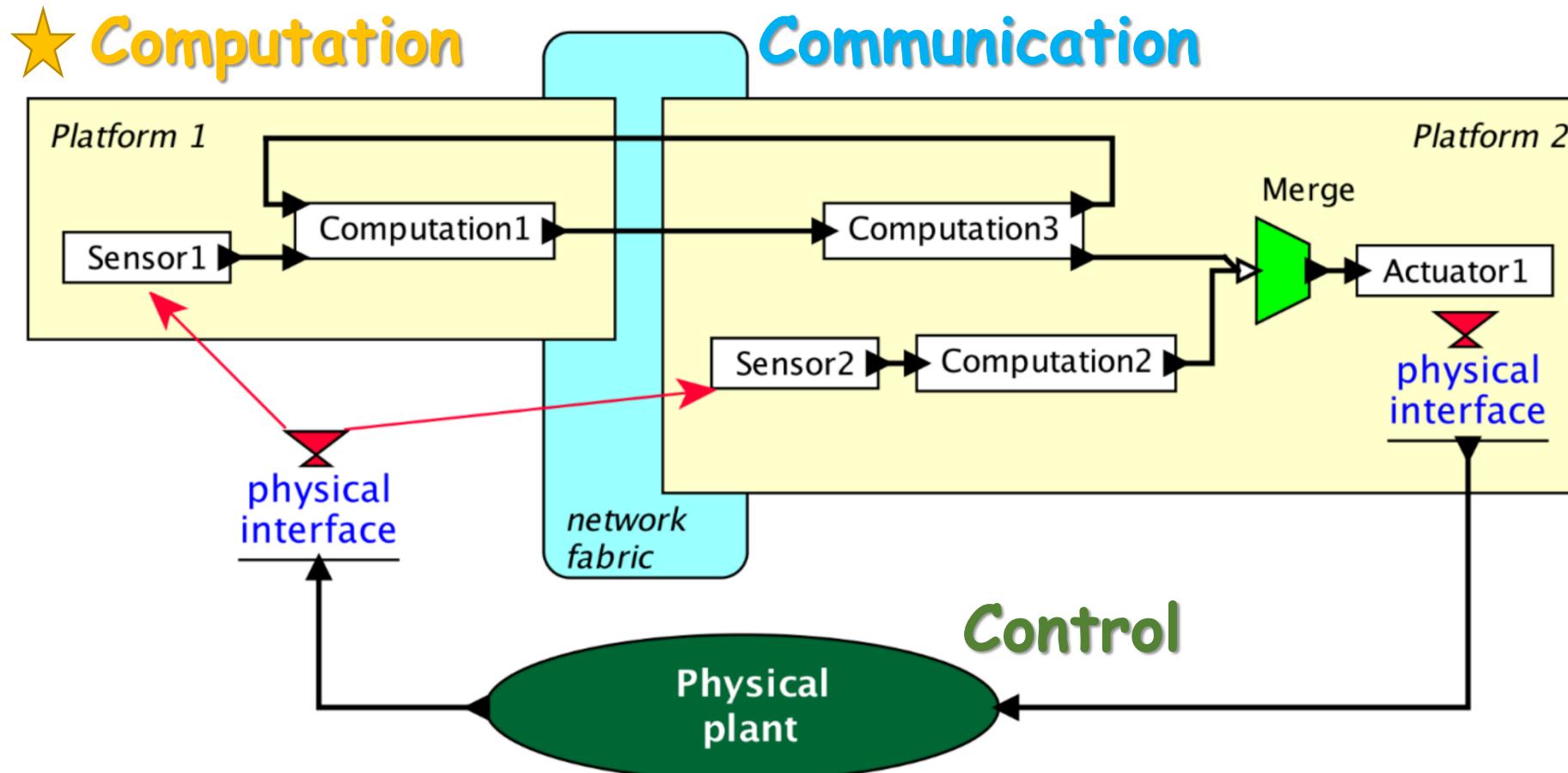
- Cyber-physical automatic control system



(Pictures are from the Internet)

Contents of future lectures

- Let's take **cyber-physical systems (CPS)** as an comprehensive example to start our EE journey



(Edward A. Lee and Sanjit A. Seshia, *Introduction to Embedded Systems, A Cyber-Physical Systems Approach*, Second Edition, MIT Press, 2017.)

Contents of future lectures

- The emphases on **computation**, **control**, and **communication** in our EE curriculum

