

# SI100B Introduction to Information Science and Technology

(Part 3: Electrical Engineering)

## Lecture #1 Introduction

Instructor: Junrui Liang (梁俊睿)  
Nov. 6<sup>th</sup>, 2020

# Instructors

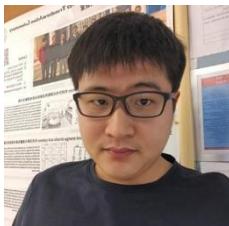
- Instructor: Junrui Liang 梁俊睿

- Office: Room 1D-303.D, SIST Building 1
- Email: [liangjr@shanghaitech.edu.cn](mailto:liangjr@shanghaitech.edu.cn)
- Web: <http://metal.shanghaitech.edu.cn>
- 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)

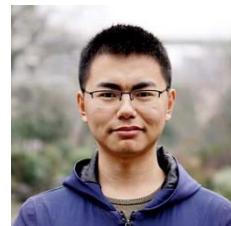


- TAs

Li Teng  
滕霧



Yiming Gao  
高一鸣



Fengxu Yang  
杨丰煦



Jiangting Xia Haochuan Wan  
夏江婷 万浩川



Zirui Wang  
王子睿



博士生

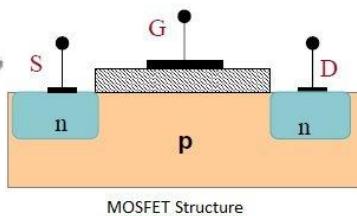
硕士生

本科生

# Logistics

- Teaching goal in eight lectures

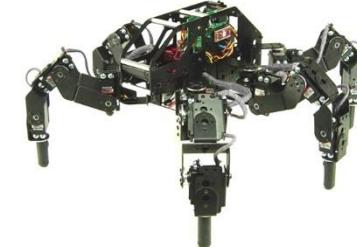
Device (1 lecture)



Circuit (4 lectures)

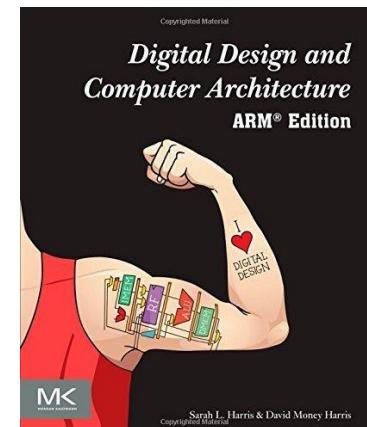
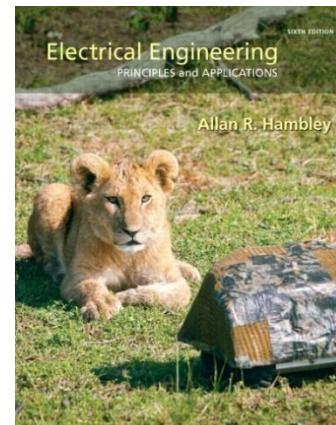


System (2 lectures)



- 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 ( $0.5\% \times 16 = 8\%$ )
- One homework assignment in each week ( $3\% \times 4 = 12\%$ )

(Pictures are from the Internet)

# Study Purpose of SI100B Part 3

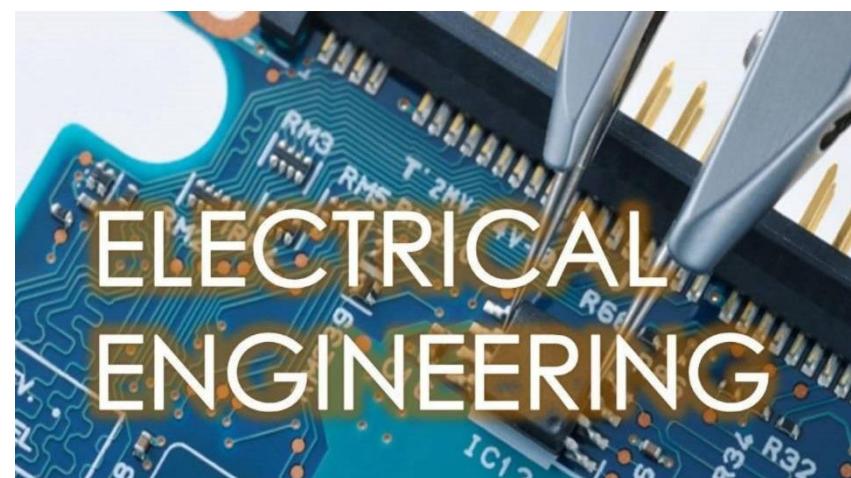
- 哲学 (bao'an) 三问
  - Who are you?
  - Where are you from?
  - Where are you going?

To answer those questions  
throughout your life



- In this part, we ask
  - What is EE?
  - Where is EE from?
  - Where is EE going?

To answer these questions  
in eight lectures

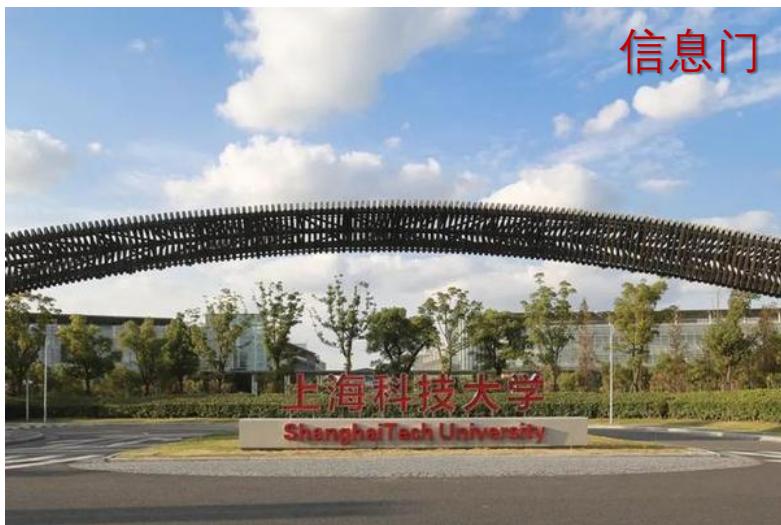


(Pictures are from the Internet)

# Lecture Outline

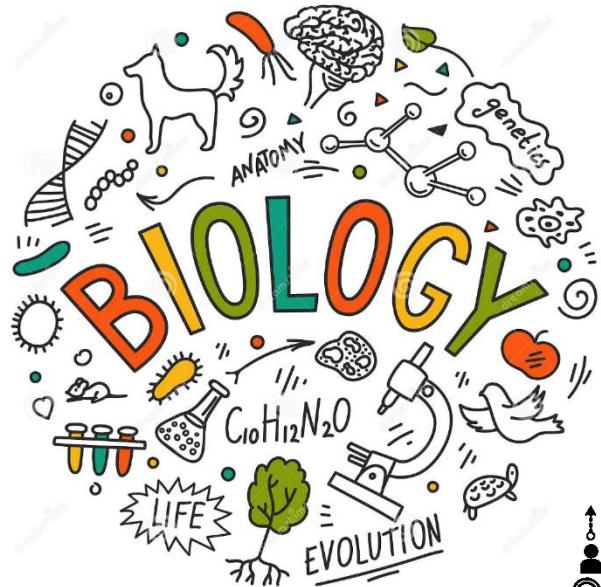
1. Prologue: information science and technology
  2. What “electrical” stands for?
  3. What “engineering” stands for?
  4. Relation between information & electricity
  5. Milestone technologies towards the information era
- (break) -----
6. EE roadmap
  7. Review: electricity in high-school physics
  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

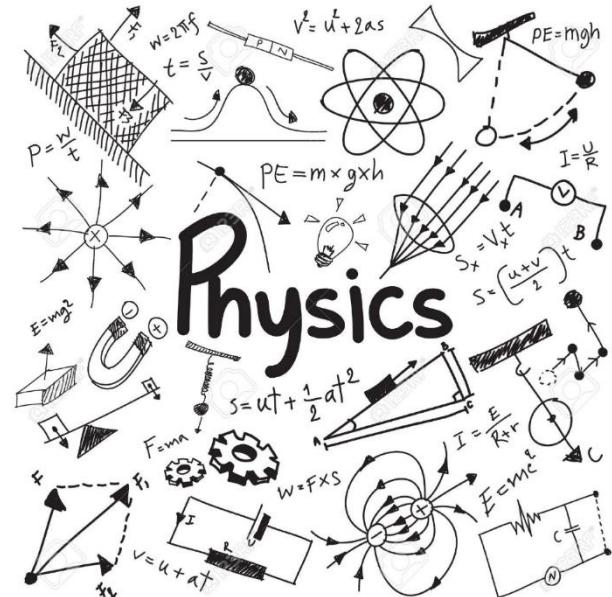


# SIST vs. SPST & SLST

- **SLST:** 研究“活”的东西



- **SPST:** 研究“死”的东西



- **SIST:**  
研究“虚拟”的东西



Needs more  
**imagination**  
and **creativity**

(Pictures are from the Internet)

# A modern way to process information & energy

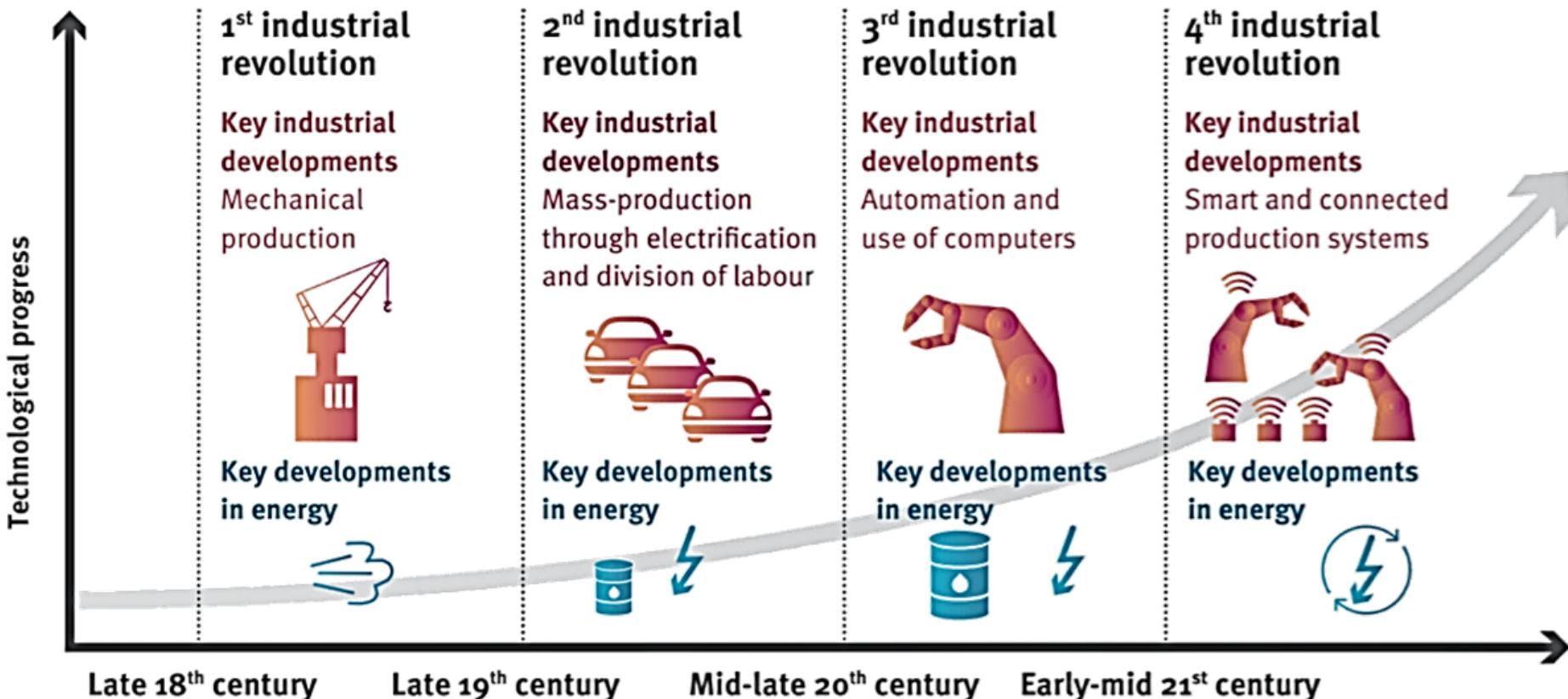
- Electrical engineering (电气工程、电机工程) design systems that have two main objectives:
  - To gather, store, process, transport, & present **information** (狭义EE)
  - To distribute, store, and convert **energy** between various forms



- 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

## Industry 4.0 - Technological pillars

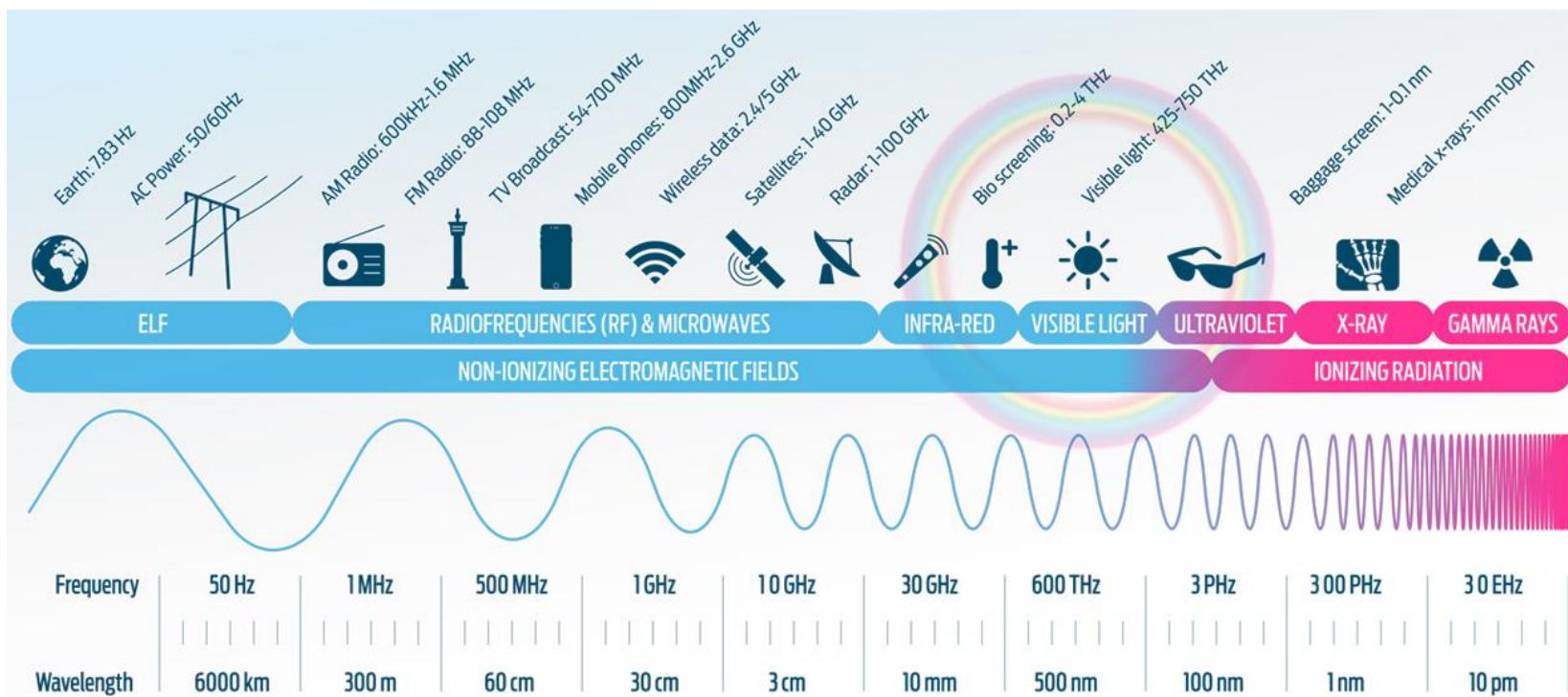
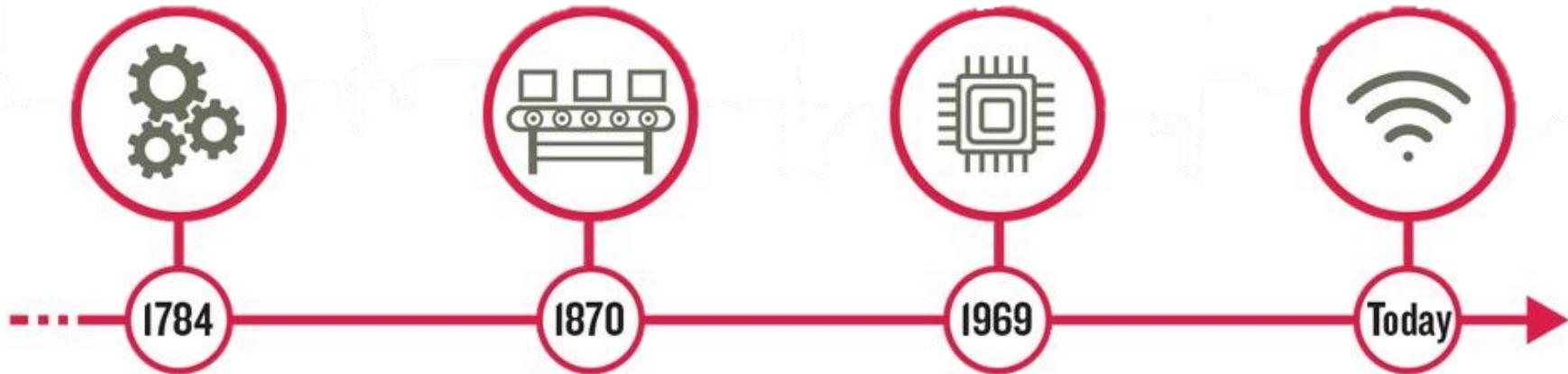


(Pictures are from the Internet)

# Made in China 2025

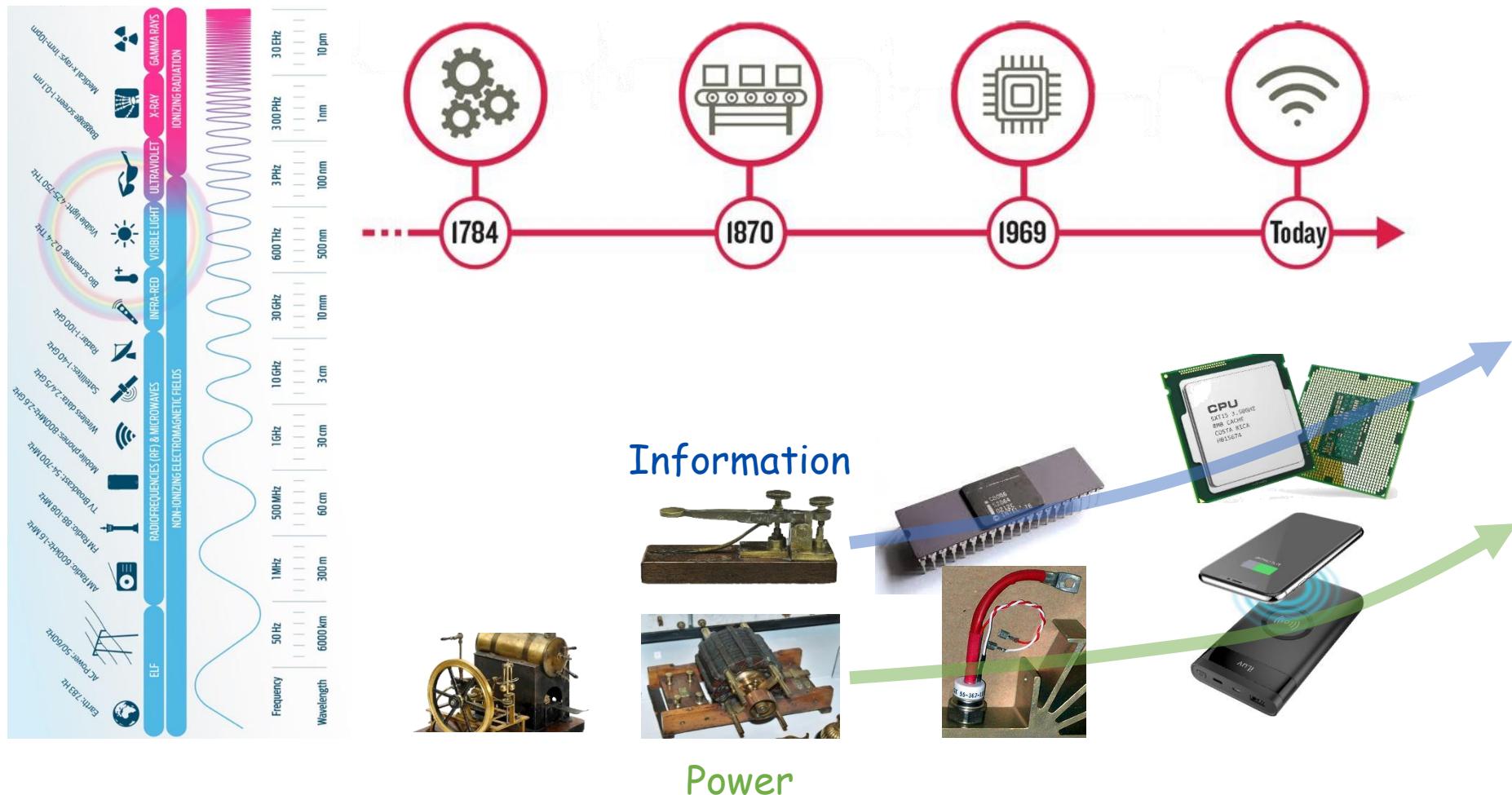


# Industrial revolutions & frequency spectrum



(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

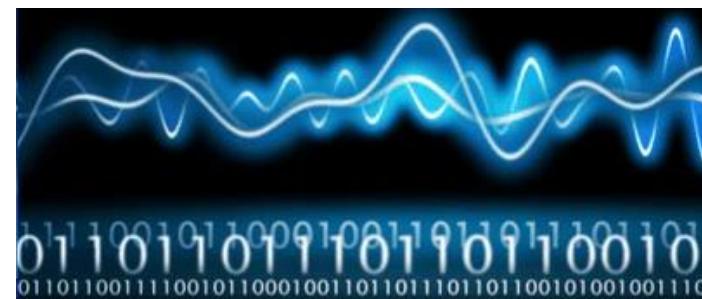
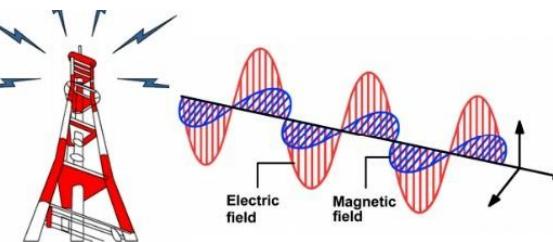


Signal → Collection → Transduction → Processing → Action

(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

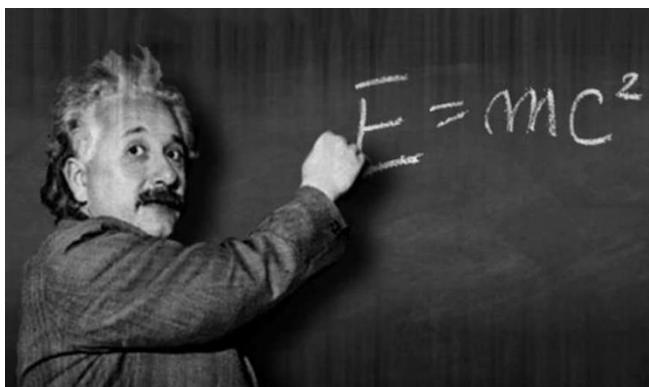
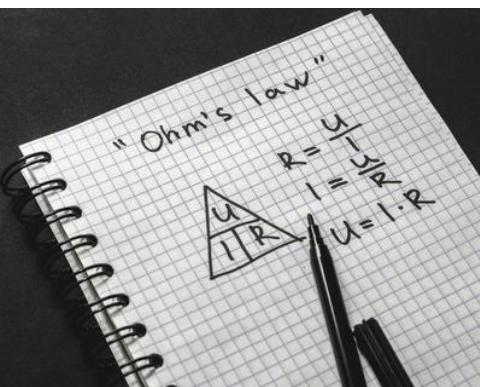


(Pictures are from the Internet)

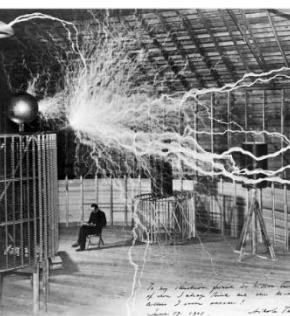
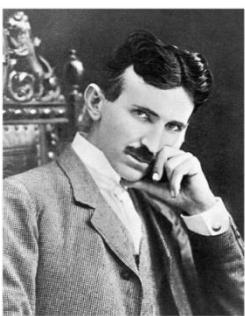
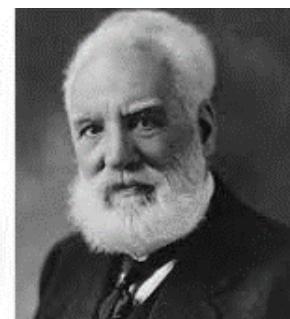
# What “engineering” stands for?

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

## Scientists



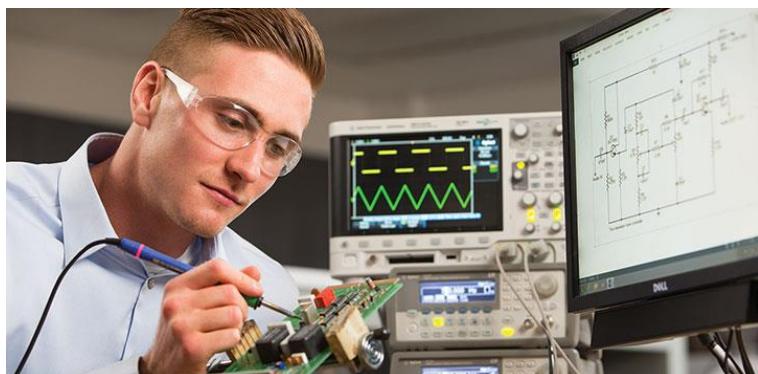
## Engineers



# Engineering branches

- Main branches

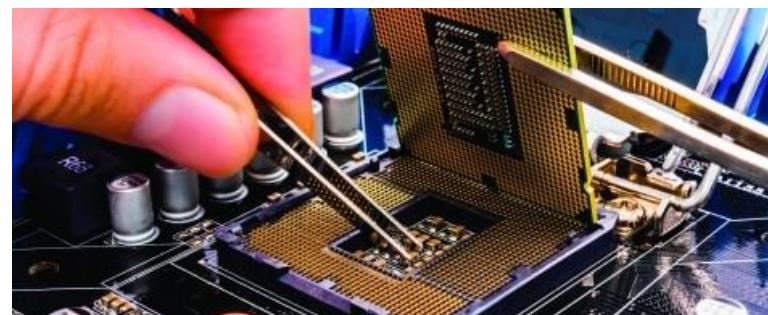
- Civil engineering
- Mechanical engineering
- Electrical engineering
- Chemical engineering



(Pictures are from the Internet)

- Interdisciplinary

- Information engineering
- Computer engineering
- Software engineering
- Biomedical engineering
- Aerospace engineering
- ...



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

# Information transfer



Wired,  
short  
distance



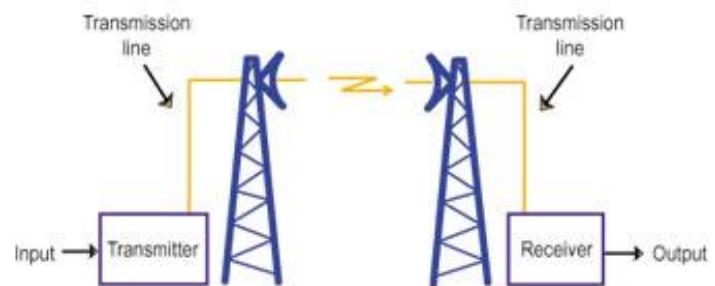
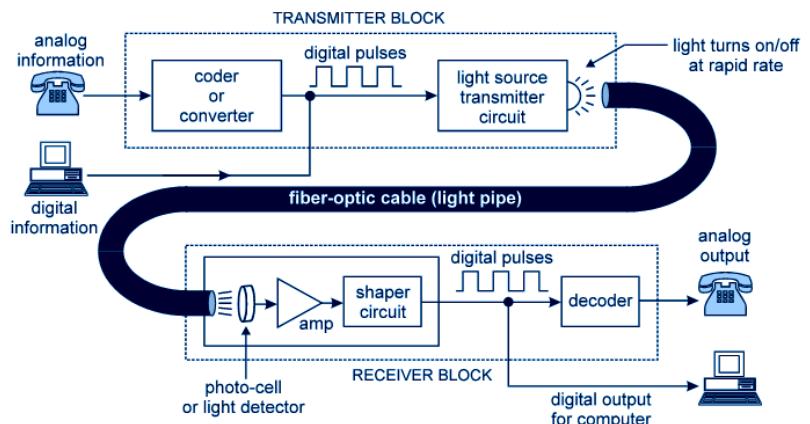
Wired,  
long  
distance



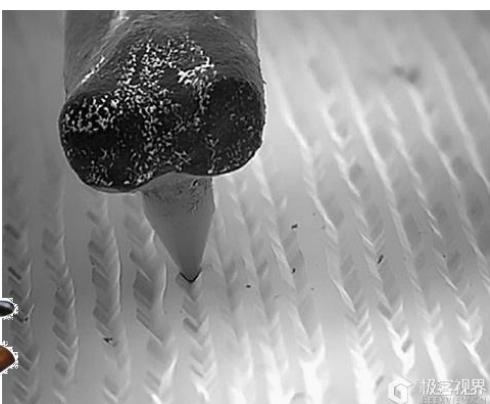
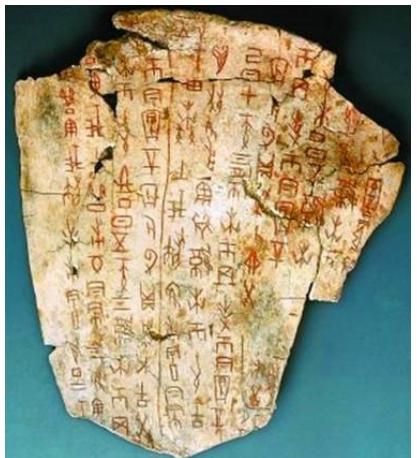
Wireless,  
short/long  
distance



(Pictures are from the Internet)

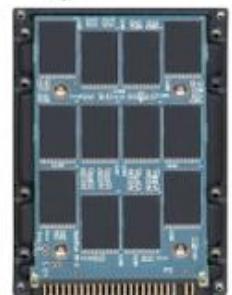
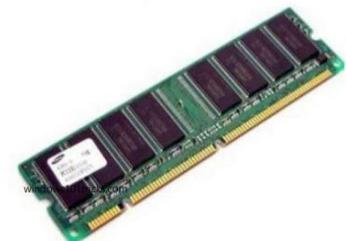


# Information storage



**RAM (Random Access Memory)**

SRAM – Static RAM vs. DRAM – Dynamic RAM

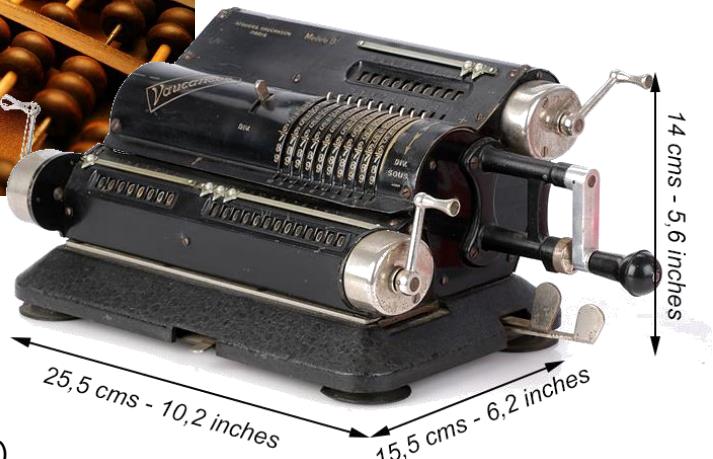
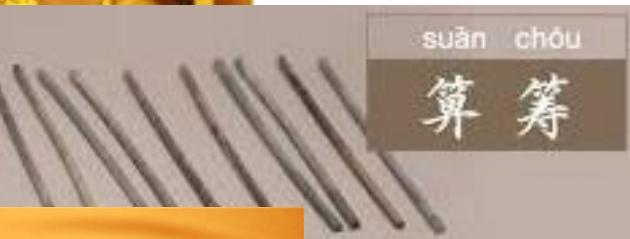
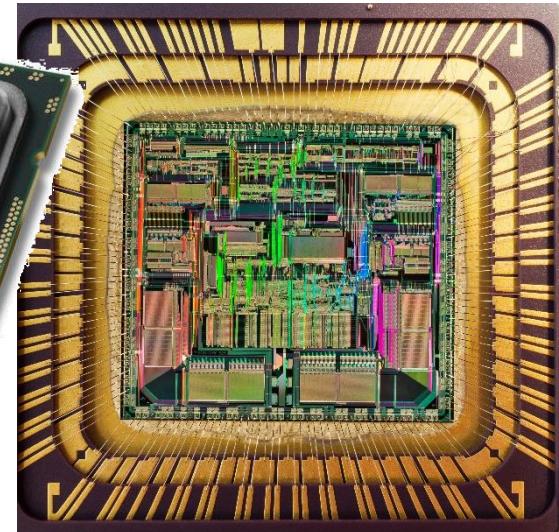


**HD**

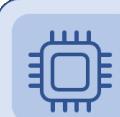
**SSD**

(Pictures are from the Internet)

# Information processing

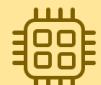


(Pictures are from the Internet)



## 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

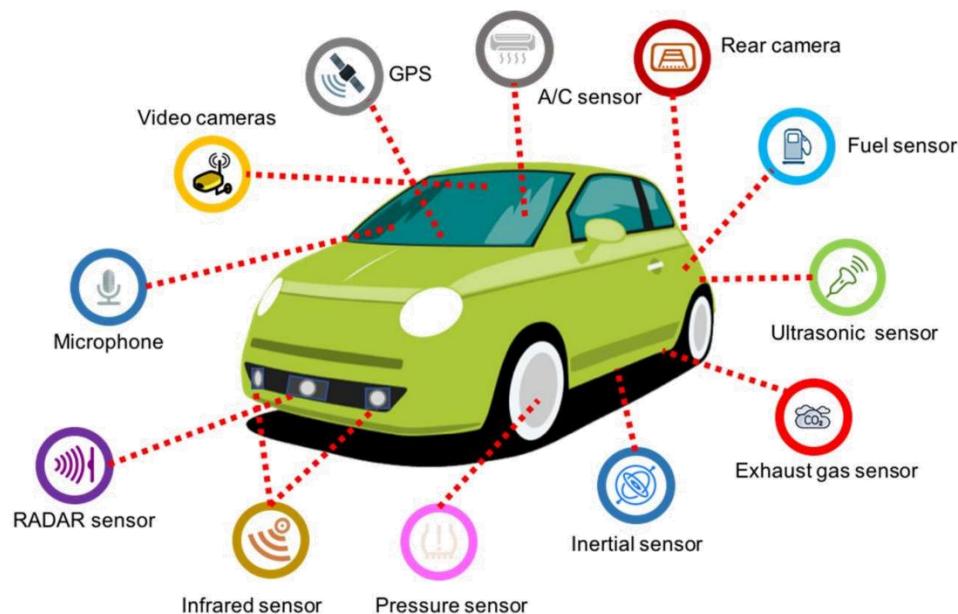
- Matrix computations
- Dense vector processing
- No custom TensorFlow operations



## FPGA

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

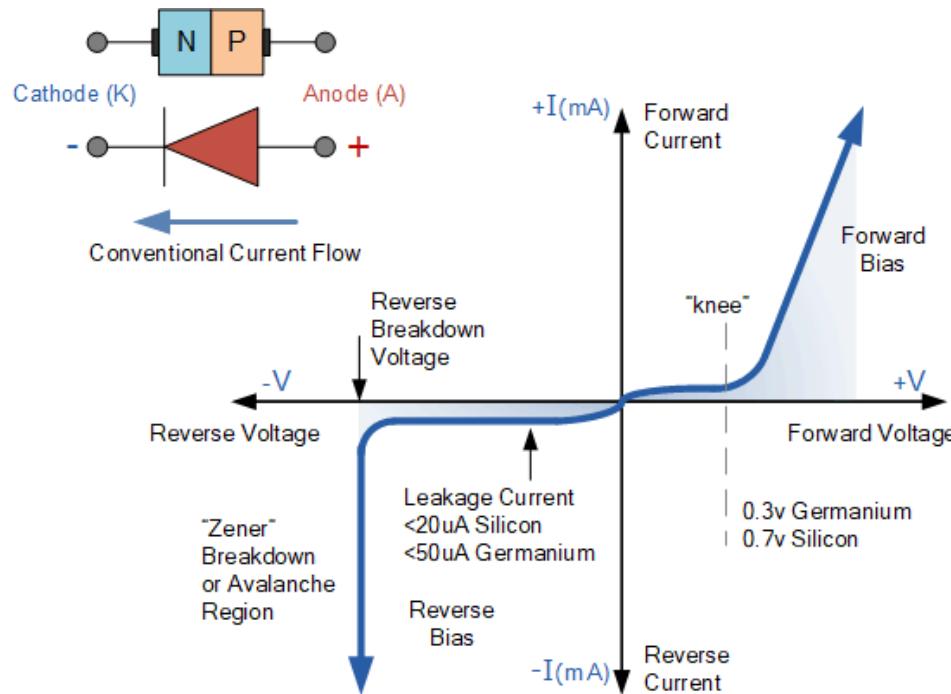
# Information acquisition and execution



(Pictures are from the Internet)

# Semiconductors and transistor effect

- Solid-state devices



- 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



- Shockley diode equation

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

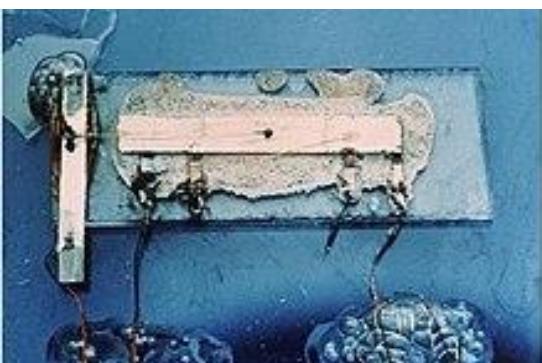
(Pictures are from the Internet)

# Integrated circuit

- Modern IC



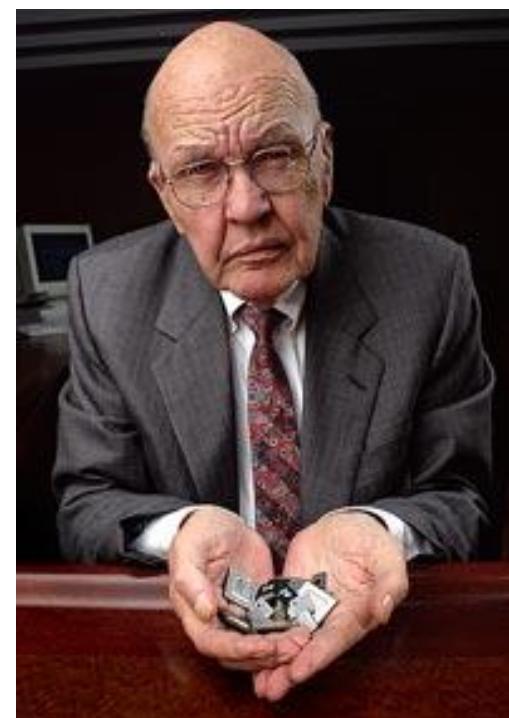
- The first IC on Germanium (1958)



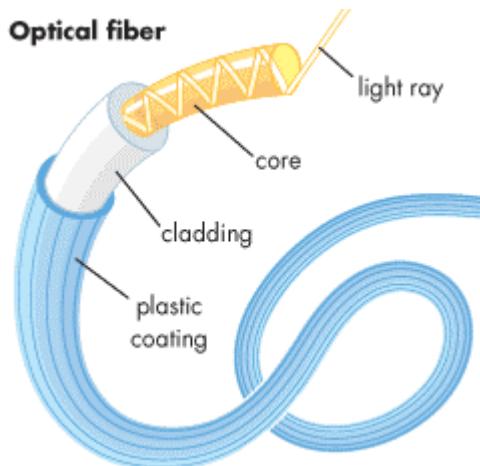
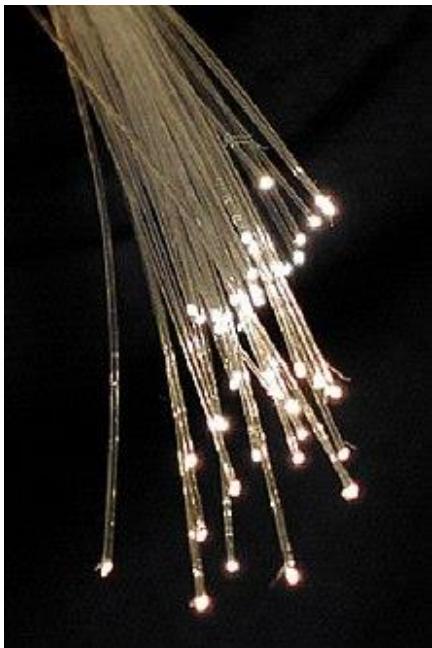
(Pictures are from the Internet)

- 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



## Fiber vs. Copper

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

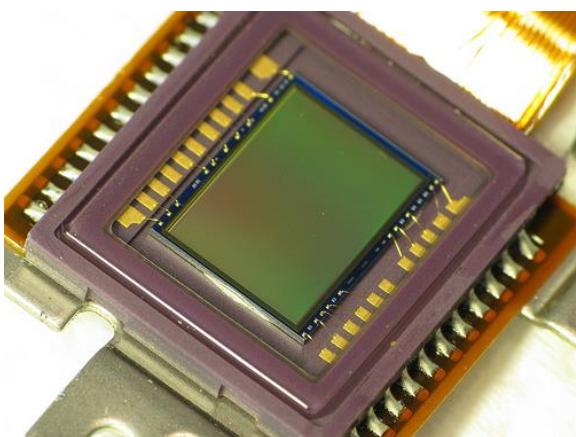
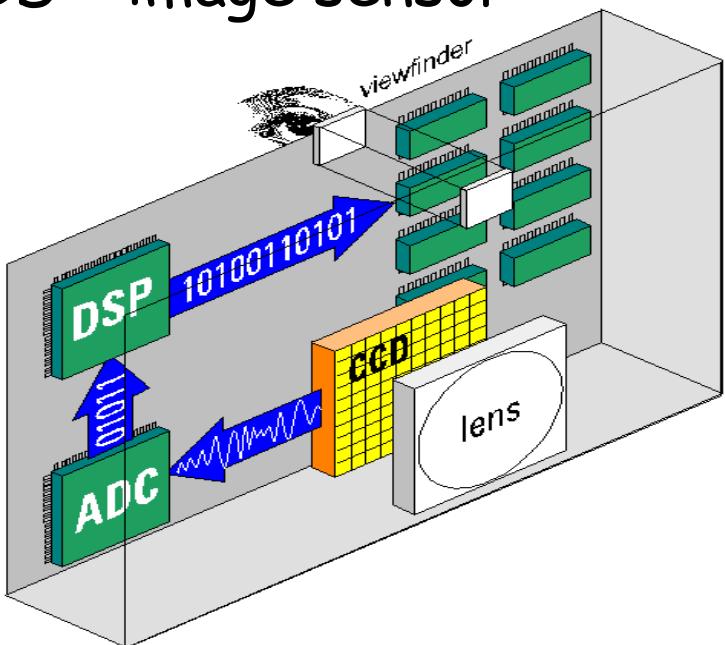
- Charles K. Kao 高锟  
(Father of fiber optics)
  - 2009 Nobel Prize in Physics for "groundbreaking achievements concerning the transmission of light in fibers for optical communication"



(Pictures are from the Internet)

# Charge-coupled device (CCD)

- CCD - image sensor



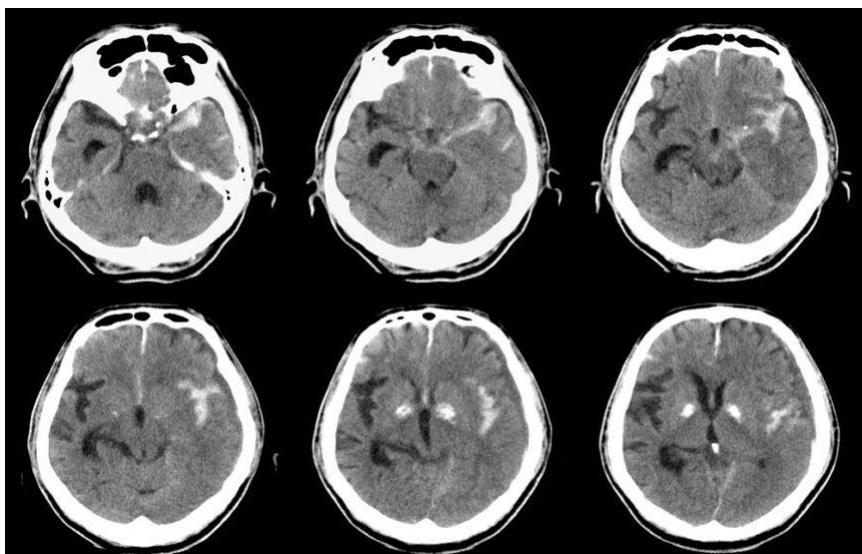
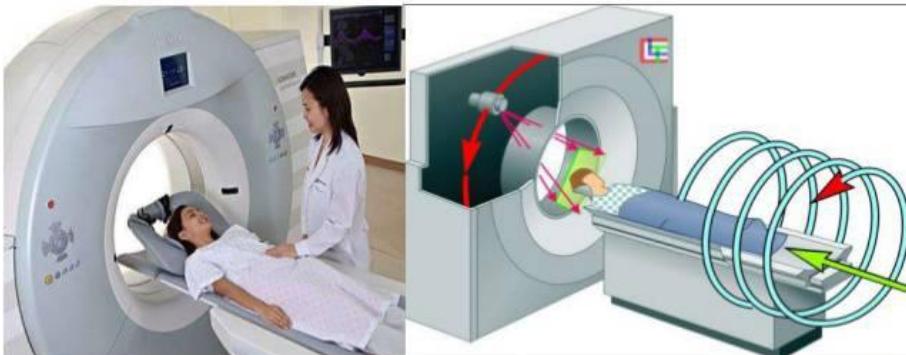
- Willard Boyle and George E. Smith  
(Fathers of digital photography)
  - 2009 Nobel Prize in Physics for "their invention of the CCD concept"
  - Invented at the Bell Labs



(Pictures are from the Internet)

# Computed tomography (CT) scan

## Computed Tomography Scan

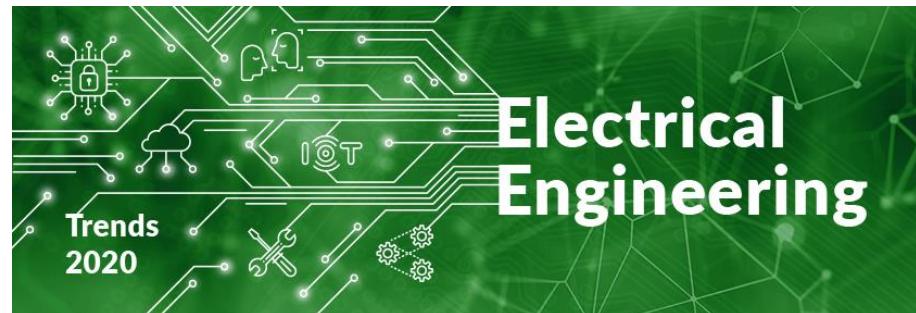


- The 1979 Nobel Prize in Physiology or Medicine was awarded jointly to South African American physicist **Allan M. Cormack** and British electrical engineer **Godfrey N. Hounsfield** "for the development of computer assisted tomography."

(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

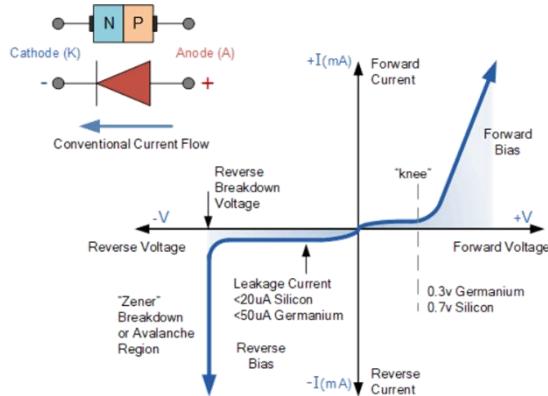


9. The Internet of Things (IoT)
10. Increased use of drones
11. A boost in the implementation of sustainable energy
12. Energy storage and better batteries
13. Robotics

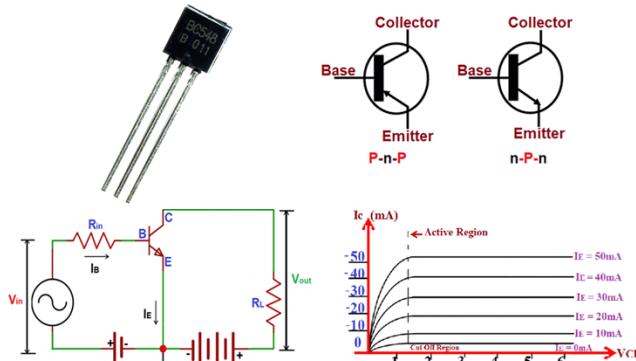
(<https://skelia.com/articles/electrical-engineering-the-13-most-influential-trends-to-watch-in-2020/>)

# What you can learn from the EE curriculum?

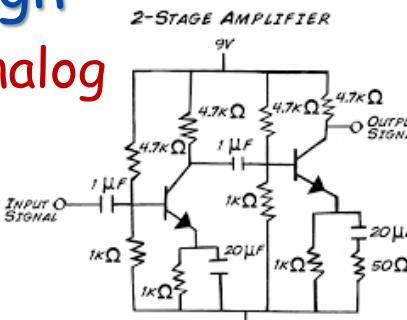
- Device physics
  - Diode 二极管
- Circuit /'sɜːrkɪt/ design
  - Analog
- System design



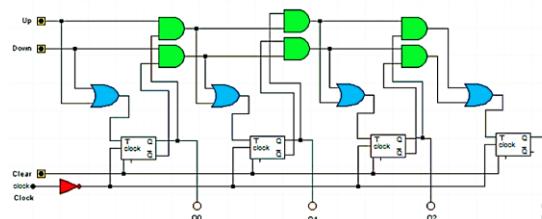
- Transistor 晶体管  
(原意 trans-resistor)



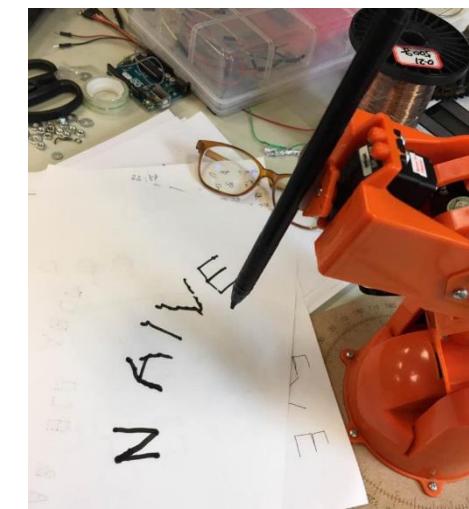
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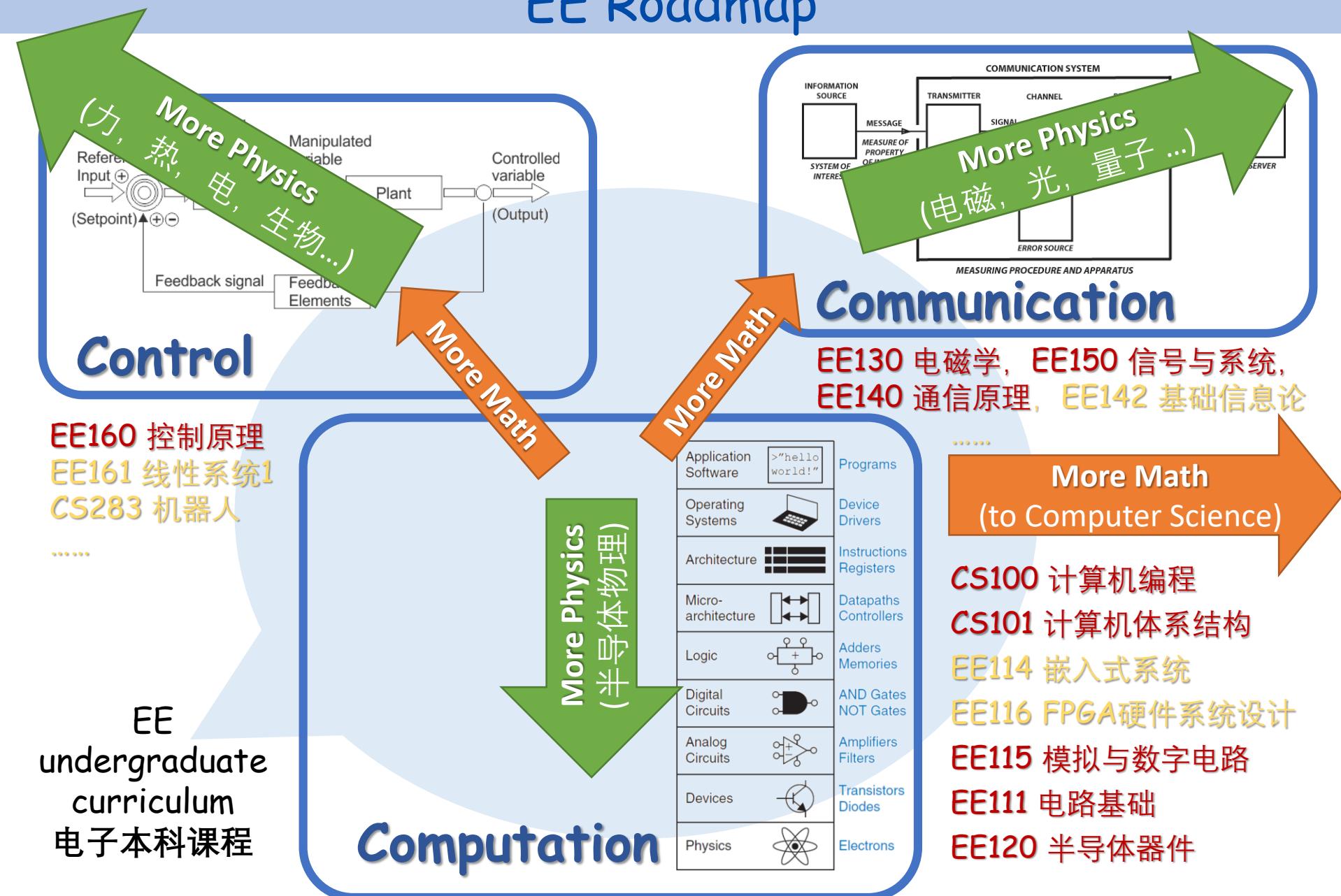
- Digital



- Hands-on experience



# EE Roadmap



# 电子信息工程专业本科生-专业选修课分类图

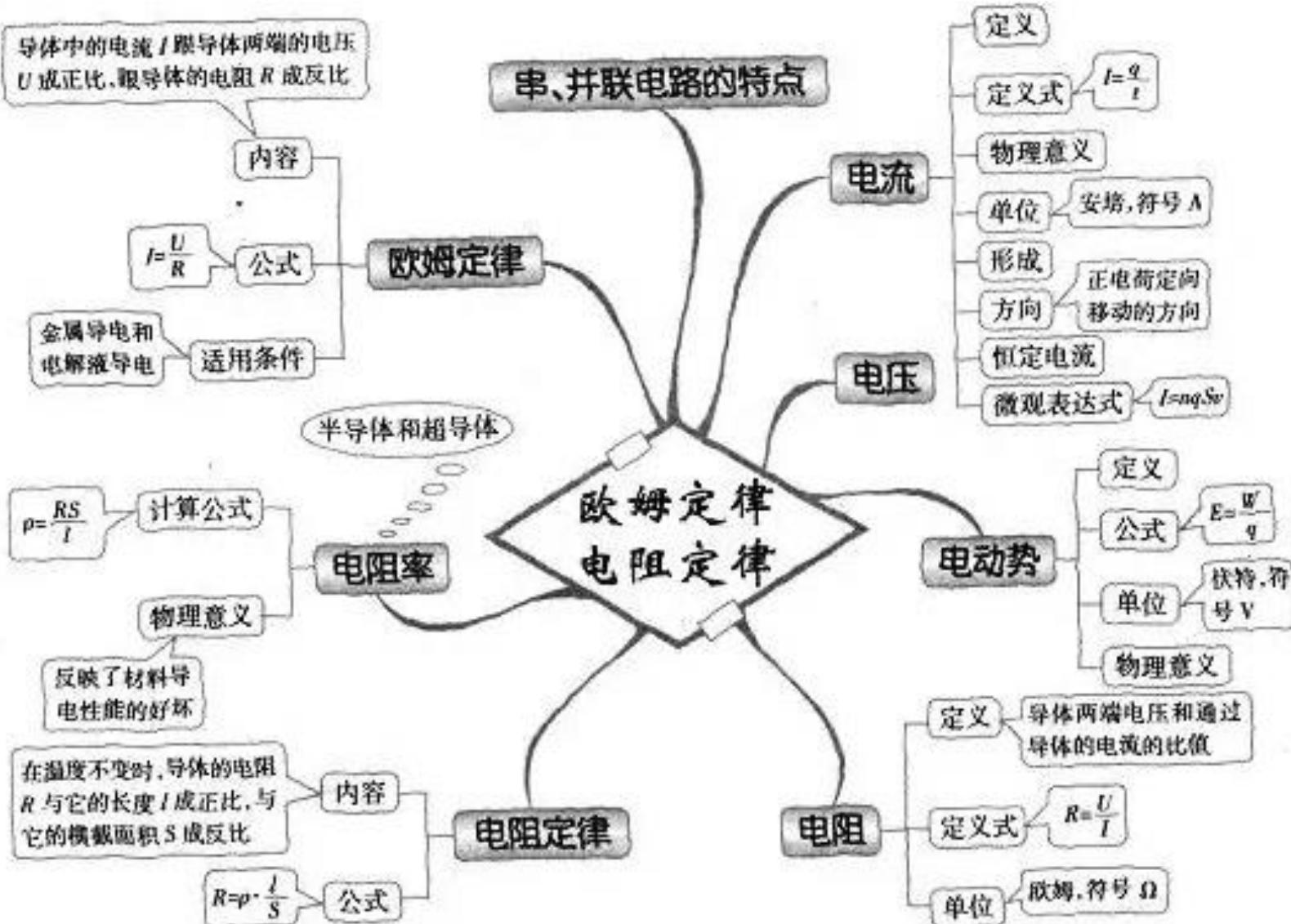
Horizontal 横向

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D) 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D) 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 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D) 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D) 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D) 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

Vertical 深度

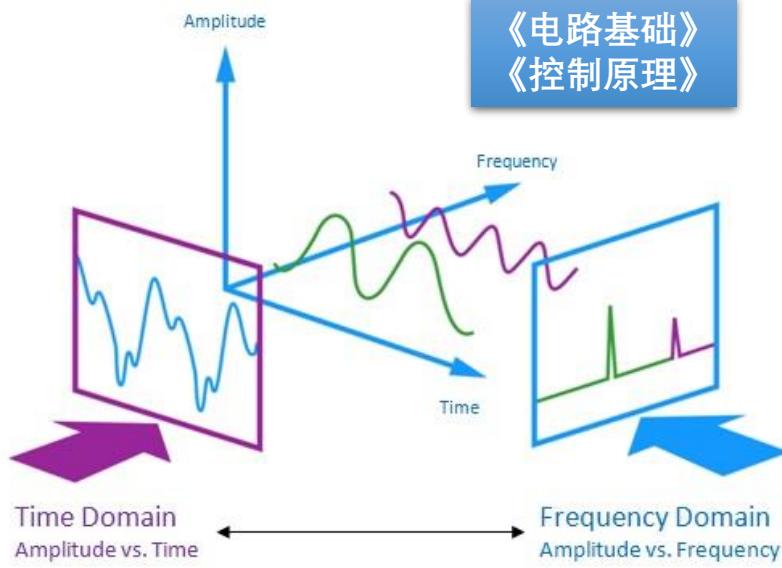
- **Compulsory courses  
必修课**
- **Professional core courses  
专业核心课**
- **Professional advanced courses  
专业进阶课**
- **Consult your mentor from time to time!**

# Electricity in high-school physics



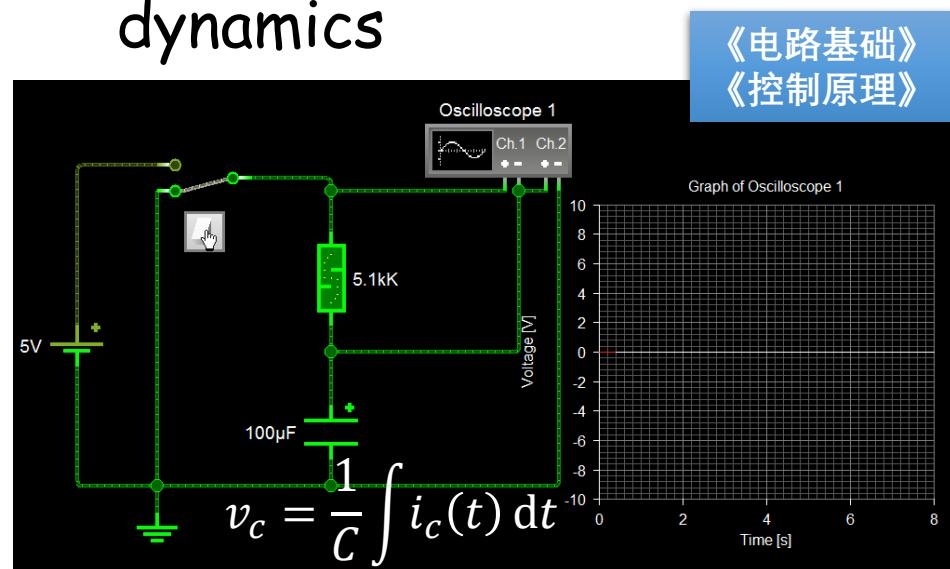
# Dynamic system 动态系统

- Opposite to static system
- Particle or ensemble of particles whose **state varies over time**
- Obeys **differential equations** involving time derivatives

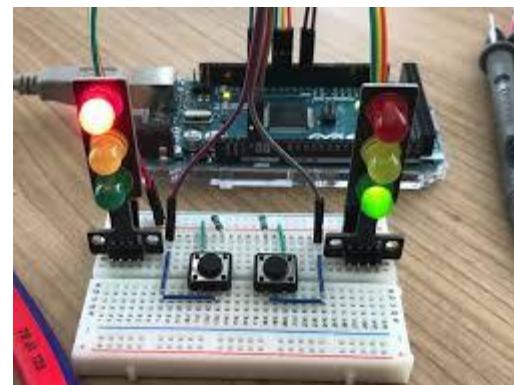


(Pictures are from the Internet)

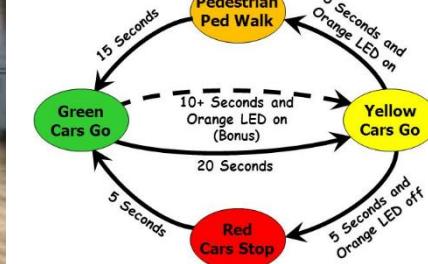
- Physical (continuous) dynamics



- Discrete dynamics



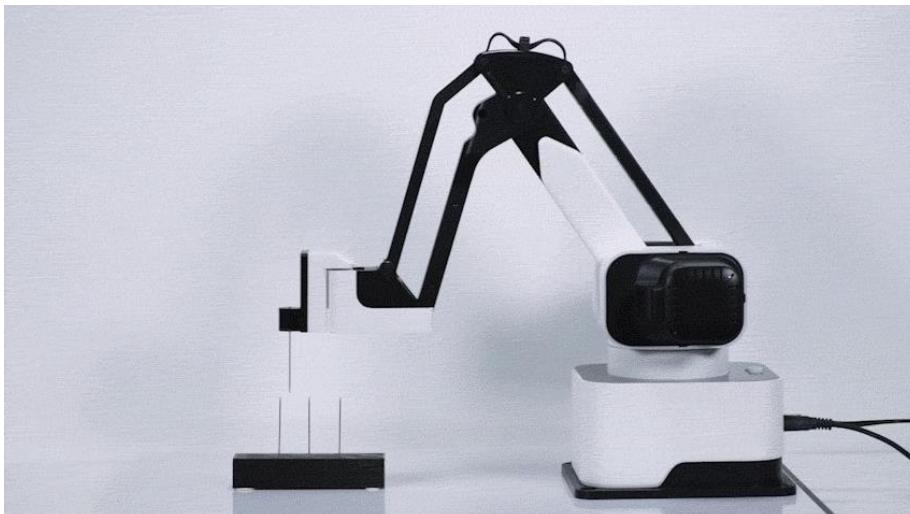
《数字电路》  
《嵌入式系统》  
《FPGA》



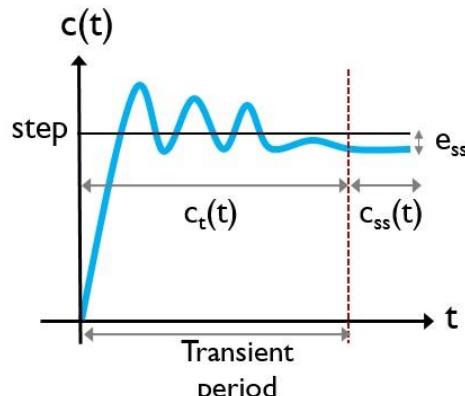
# Time domain & frequency domain 时域与频域

- Why time-domain analysis?

We, human being moves over time.



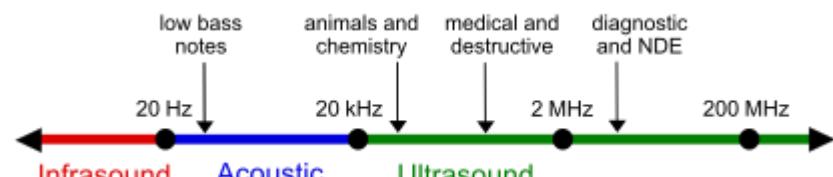
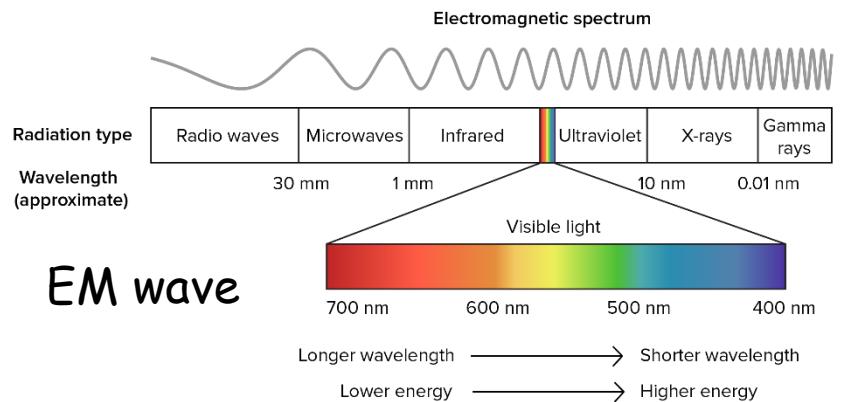
Imaging to work with a chattering robot arm, any harmful effect?



(Pictures are from the Internet)

- Why frequency-domain analysis?

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



Sound wave

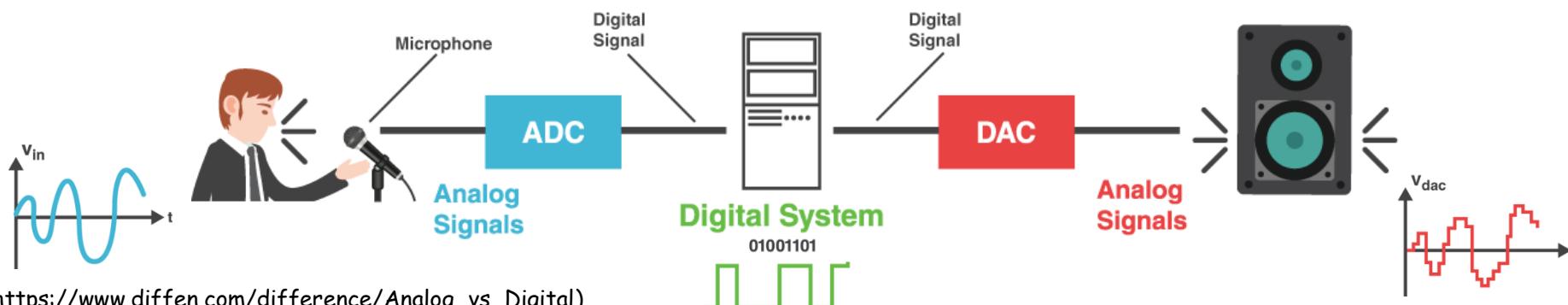
《电路基础》  
《信号与系统》  
《控制原理》

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



# 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

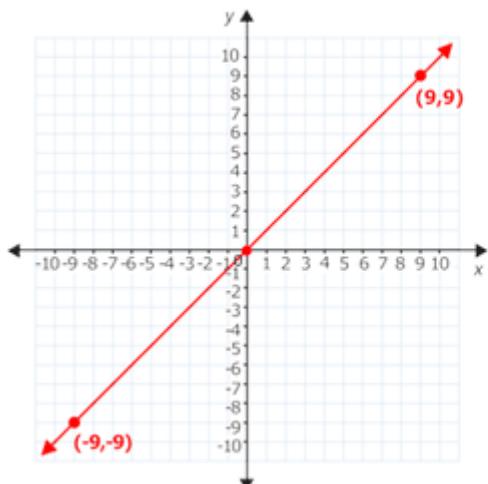
- Additivity

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

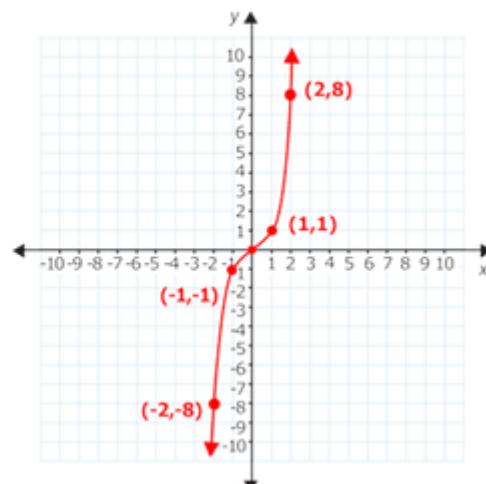
- Homogeneity of degree 1

$$f(\alpha x) = \alpha f(x) \text{ for all } \alpha$$

Linear function

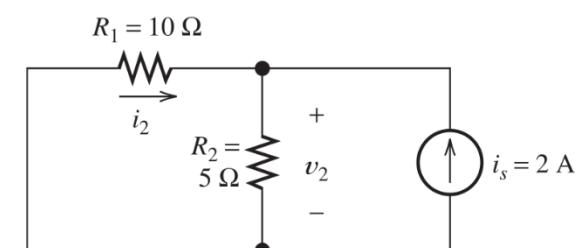
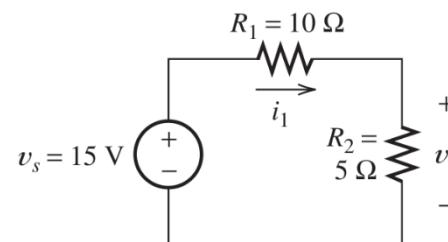
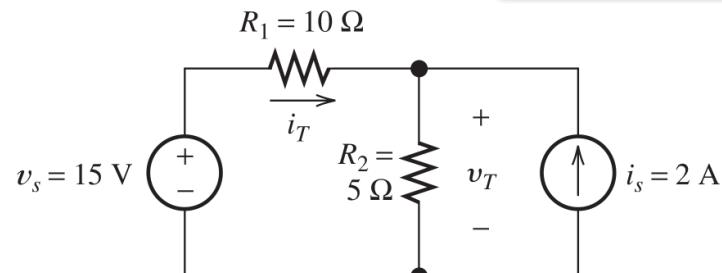


Nonlinear function



- Superposition  
线性叠加

《信号与系统》  
《控制原理》  
《线性系统》



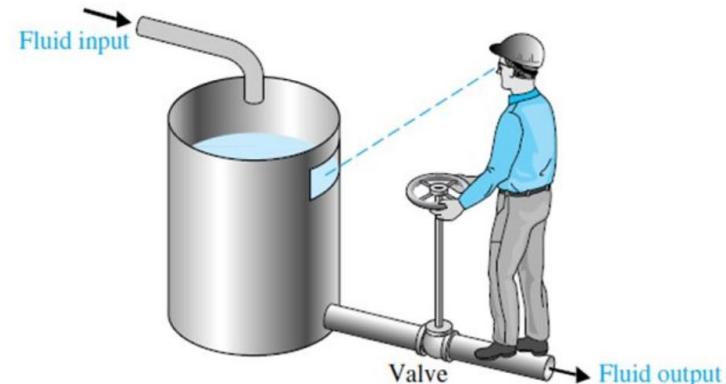
$$v_T = v_1 + v_2$$

# Contents of future lectures

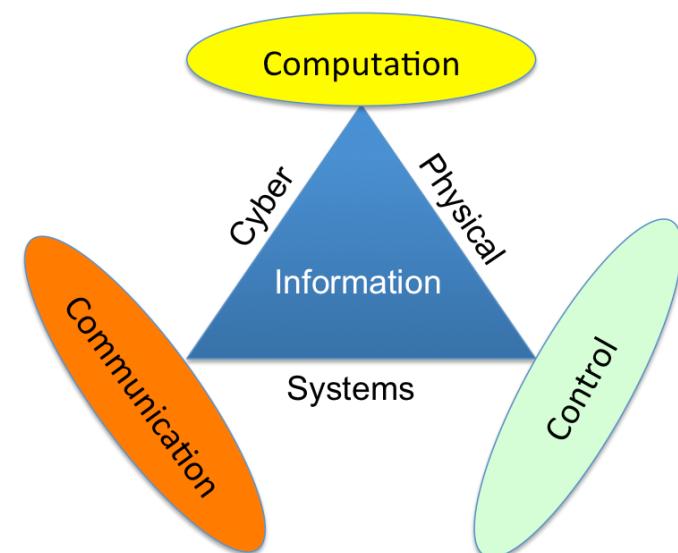
- Manual control system



Signal → Collection → Transduction → Processing → Action



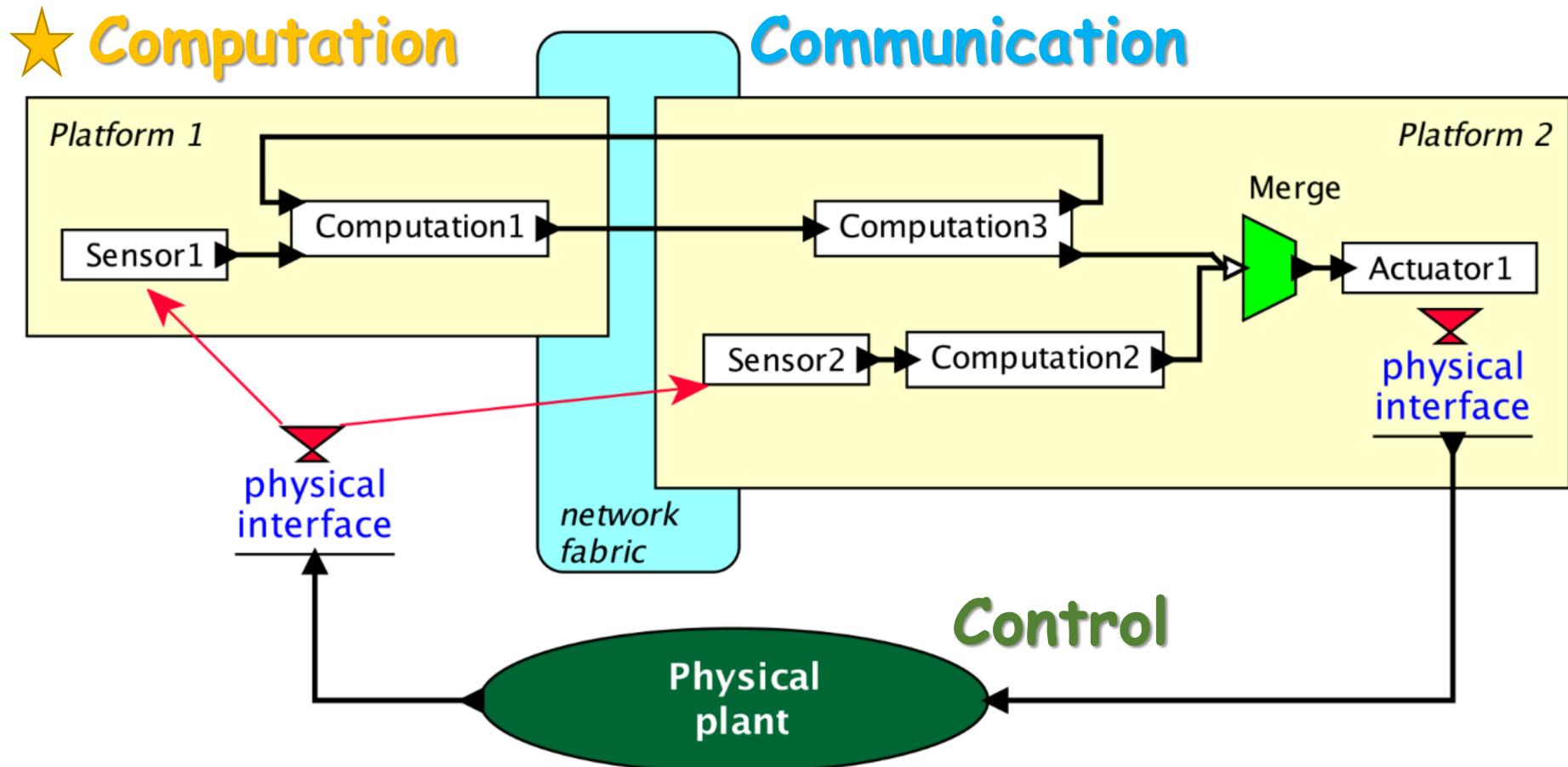
- Cyber-physical automatic control system



(Pictures are from the Internet)

# Contents of future lectures

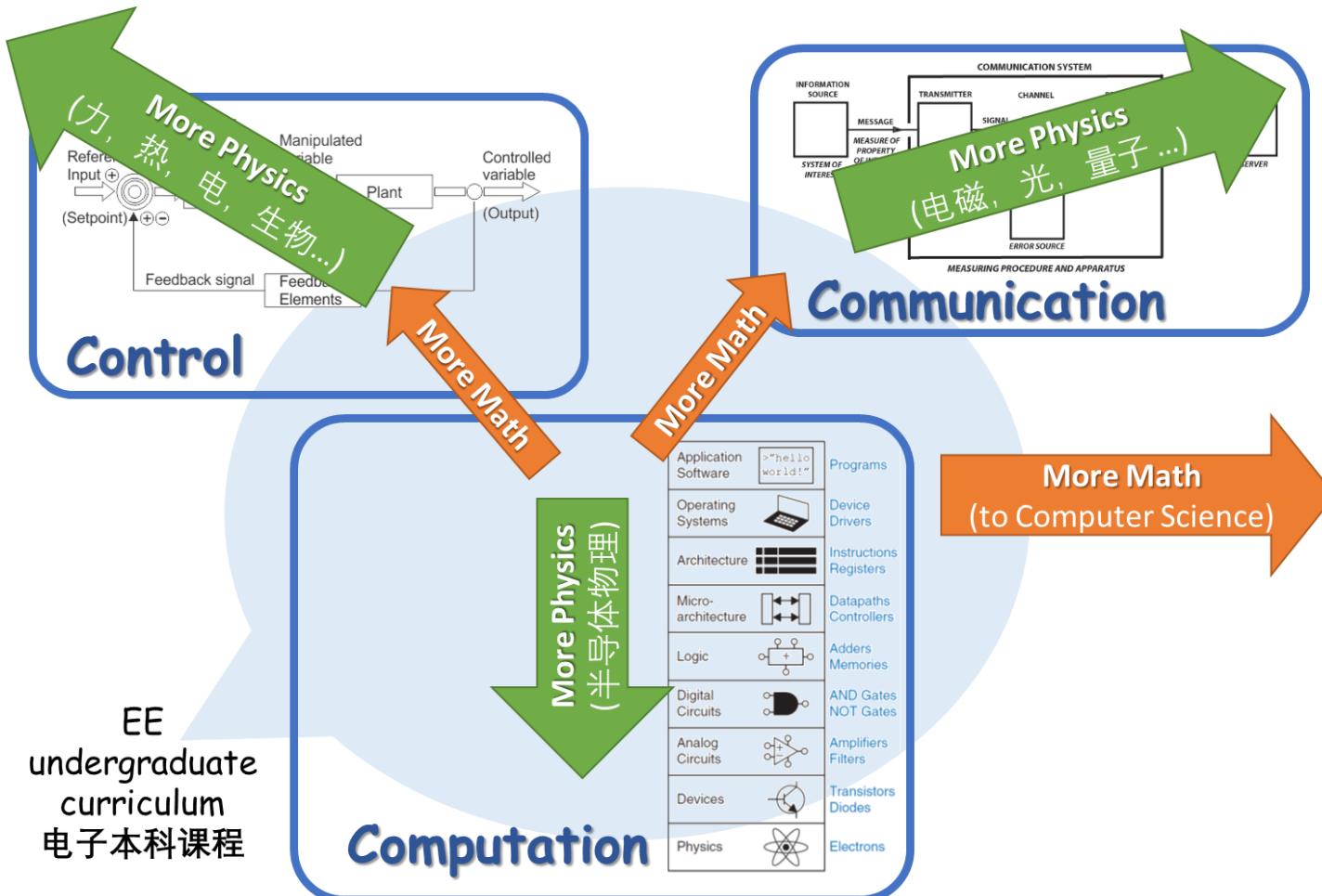
- Let's take **cyber-physical systems (CPS)** as an comprehensive example to start our EE journey



(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

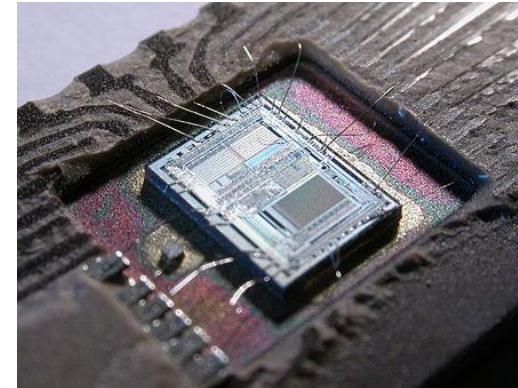


# Contents of future lectures

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



Devices (1)



Circuits (4)

Systems (2)



(Some pictures are from the Internet)

# Independent Study

- High-school style

- Specific space (固定教室)
- A few subjects (科目少)
- Repeating contents (反复复习)
- Monotonous media (媒介单一)
- Learning for exams (在考中学)
- Single purpose (高考独木桥)
- 知识改变命运



(Pictures are from the Internet)

- University style

- Open environment (开放式环境)
- Many subjects (许多科目)
- Few recitation (极少重复)
- Multi-media (多种媒介)
- Learning by doing (尝试在做中学)
- Diversity (出路差异化)
- 见识决定宽度，能力决定高度

