University Physics

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Chapter 1 Introduction and Vectors

§1 About Physics

- **What is physics?**
- **Why study physics?**
- **How to study physics?**

- 评价方式：
  作业+考勤+期中+课堂回答问题：**40%**
  期末：**60%**
  作业+考勤：以教学云平台的数据为准。
- 教学内容：
  力学+振动与波+电磁学

What is physics?

- 马文蔚编写的《物理学教程》序言中的描述：“物理学是研究**物质**的基本结构、**基本运动形式**以及**相互作用**规律的科学。”
- 百度百科的描述：“物理学是研究**物质运动最一般规律**和**物质基本结构**的学科。作为自然科学的带头学科，物理学研究大至宇宙，小至基本粒子等一切物质最基本的运动形式和规律，因此成为其他各自然科学学科的研究基础。”

- **物质**为构成宇宙间一切物体的**实物**和**场，**其共同特征是：都具有质量和能量。
- 基本运动形式：

➢ 机械运动---**牛顿力学**、机械振动与机械波、声波

➢ 热运动--- 热力学与统计物理

➢ 电磁运动---**电磁学**与电动力学

➢ 量子力学：研究微观物质运动现象以及基本运动规律

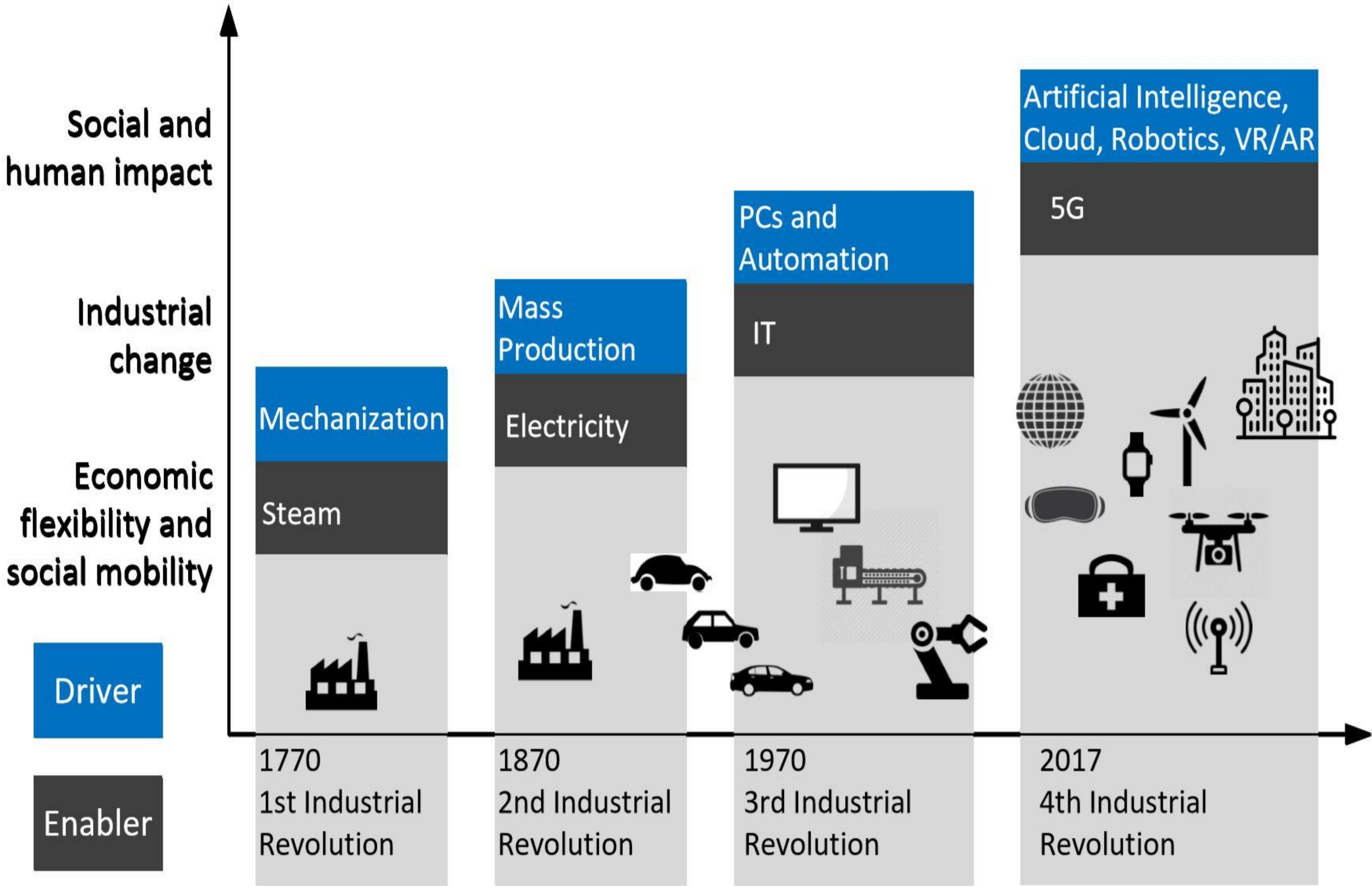
➢ 狭义相对论：研究物体的高速运动效应以及相关的动力学规律

- 四种基本相互作用是：万有引力、电磁力、强相互作用、弱相互作用。
  - 电磁相互作用：是带电粒子与电磁场的相互作用以及带电粒子之间通过电磁场传递的相互作用，在宏观尺度的距离中起作用
  - 强相互作用：核子之间的核力，短程力，作用范围10^{-15}米
  - 弱相互作用：短程力，

Why study physics?

- 物理学是最基本的自然科学之一，是工程技术的基础。“没有昨日的基础科学就没有今日的技术革命”。几乎所有的重大新(高)技术领域的创立，事先都在物理学中经过长期的酝酿。
- 物理学的方法和科学态度：提出命题 → 理论解释 → 理论预言 → 实验验证 →修改理论

4th "Industrial" Revolution Powered by 5G



How to study physics?

- 著名物理学家费曼说：科学是一种**方法**，它教导人们：一些事物是怎样被了解的，什么事情是已知的，了解到了什么程度，如何对待疑问和不确定性，证据服从什么法则；如何思考事物，做出判断，如何区别真伪和表面现象？
- 著名物理学家爱因斯坦说：发展**独立思考和独立判断**的一般能力，应当始终放在首位，而不应当把专业知识放在首位.如果一个人掌握了他的学科的基础理论，并且学会了独立思考和工作，他必定会找到自己的道路，而且比起那种主要以获得细节知识为其培训内容的人来，他一定会更好地适应进步和变化 。

学习大学物理注意的问题

1.注意大学物理与中学物理的区别

内容上的差别

中学物理特点： 以物理知识点的传授为主，内容简单和基础，数学工具简单， 研究特殊的问题

大学物理特点： 以物理思想和知识整体结构的学习为主，内容系统、深入和完整，物理与数学联系非常紧密（高等数学），研究普遍性的问题

教学方法上的区别

中学物理特点： 形象和生动，内容少、课时多、练习量大（作业、测验、考试等），学习的主体意识不强，对教师的依赖性较强

大学物理特点： 抽象，注重理论上的分析、推理和论证，逻辑性和系统性强，内容多，信息量大，学时少，学生自主学习能力要求高

学习大学物理注意的问题

2. 众多物理量为矢量（牛顿力学又称之为矢量力学）

物理量为矢量：位置矢量、位移、速度、加速度、力、冲量、动量、力矩、角动量等

- 掌握矢量性质和运算法则
- 可借助几何图形理解矢量的问题
- 矢量与复数有一定的对应关系
- 许多情况下，建立坐标系把矢量问题转化为代数量求解，化繁为简
- **印刷体的矢量为黑体（斜体），书写过程必须写矢量号**

学习大学物理注意的问题

3.高等数学（微积分）的灵活运用

- 学习物理内容的核心是物理知识的掌握及其运用，涉及到如何用数学处理物理问题，应从物理角度理解问题中涉及到的数学问题，比如选取微元（不是数学无穷小，而是物理无限小），坐标轴建立后物理量正负号的含义等
- 应掌握基本的高等数学微积分知识（极限、求导、一元积分等）

4.学习过程中应注意的问题

- 认真学习教材，深刻理解基本理论，克服困难，独立自主做适量习题，这非常有利于分析问题和解决问题能力的提升
- 一定要摒弃中学一些不好的习惯，比如不求甚解、只刷题不注重看书（很难真正学懂）、死背公式、解题时没有逻辑等

Reference Books

- **Physics for Scientists and Engineers with Modern Physics, 3rd Ed. D. C. Giancoli** 著，滕小瑛改编，高等教育出版社
- **Sears and Zemansky's University Physics:** 西尔斯物理学，**Young & Freedman**，机械工业出版社
- 《大学物理学》**(**三本**)**，吴百诗，高等教育出版社，**2004**
- 《物理学教程（第三版）》，马文蔚，周雨青，解希顺编，高等教育出版社，**2016**年
- 《大学物理双语课程解题指导》（第**2**版），北邮出版社，**2015**年
- 上课课件及部分参考资料：教学云平台
- 讨论平台：**QQ**群**492405130**、教学云平台

§ 2 Idealized Models

- Idealized models play a crucial role in science and technology
  - An idealized model is a simplified version of a physical system that would be too complicated to analyze in full detail.
  - An idealized model makes us to overlook quite a few minor effects and to concentrate on the most important features of the system.
- The idealized model of Particle (质点)
  - The particle model allows the replacement of an extended object with a particle which has mass, but zero size.
  - Two conditions for using the particle model are:
    - **The size of the actual object is of no consequence in the analysis of its motion**
    - **Any internal processes occurring in the object are of no consequence in the analysis of its motion**
- Another examples of idealized model used in physics
  - Rigid body (刚体), point charge (点电荷), ideal gas (理想气体), and so on.

§ 3 Measurements, Estimating

P3-10

- Significant figures（有效数字）.
  - How to denote the significant figures for a number?

    Counting from the left and ignoring leading zero, keep all digits up to the first doubtful one.
  - Scientific notation.

    When the number is too small or too large, we commonly write numbers in “powers of ten”, which is called scientific notation.

Mass of the Earth: 5,980,000,000,000,000,000,000,000kg

or 5.98×10^{24}kg

Diameter of proton（质子）: 0.000000000000001m or 10^{-15}m

Scientific notation allows the number of significant figures to be clearly expressed.

Significant figures（有效数字）

- How to treat the number of significant figures when multiplying or dividing, and adding or subtracting.

When multiplying or dividing ,the number of significant figures in the product or quotient should be no greater than the number of significant figures in the least precise of the factors.

Thus: 2.3*3.14159=7.2

In adding and subtracting, the least significant figures of the sum or difference occupies the same relative position as the least significant digit of the quantities being added or subtracted .

For example: 103.9+2.11=106.01=106.0

SI unit system（单位制）

We measure each physical quantity in its own units by comparison with a **standard.**

In 1971, the 14^{th} General Conference on Weights and Measures, The SI (International System) was adopted.

It is based on meter, second and kilogram.

It is also called metric system or mks system.

7 base units for SI unit system.

The Seven SI Base Units

Quantity		*SI Unit*: *Name*	*Symbol*	*中文*
Time	*In Mechanics*	**second**	**s**	秒
Length	*In Mechanics*	**meter**	**m**	米
Mass	*In Mechanics*	**kilogram**	**kg**	千克
Electric current		**ampere**	**A**	安培
Thermodynamic temperature		**kelvin**	**K**	开尔文
Amount of substance		**mole**	**mol**	摩尔
Luminous intensity		**candela**	**cd**	坎德拉

SI Prefixes

Factor	*Prefix*	*Symbol*	*中文*	*Factor*	*Prefix*	*Symbol*	*中文*
10^{18}	exa-	E	艾	10^{-1}	deci-	d	分
10^{15}	peta-	P	拍	10^{-2}	centi-	c	厘
10^{12}	tera-	T	太	10^{-3}	milli-	m	毫
10^{9}	giga-	G	吉	10^{-6}	micro-	μ	微
10^{6}	mega-	M	兆	10^{-9}	nano-	n	纳
10^{3}	kilo-	k	千	10^{-12}	pico-	p	皮
10^{2}	hector-	h	百	10^{-15}	femto-	f	飞
10^{1}	deka-	da	十	10^{-18}	atto-	a	阿

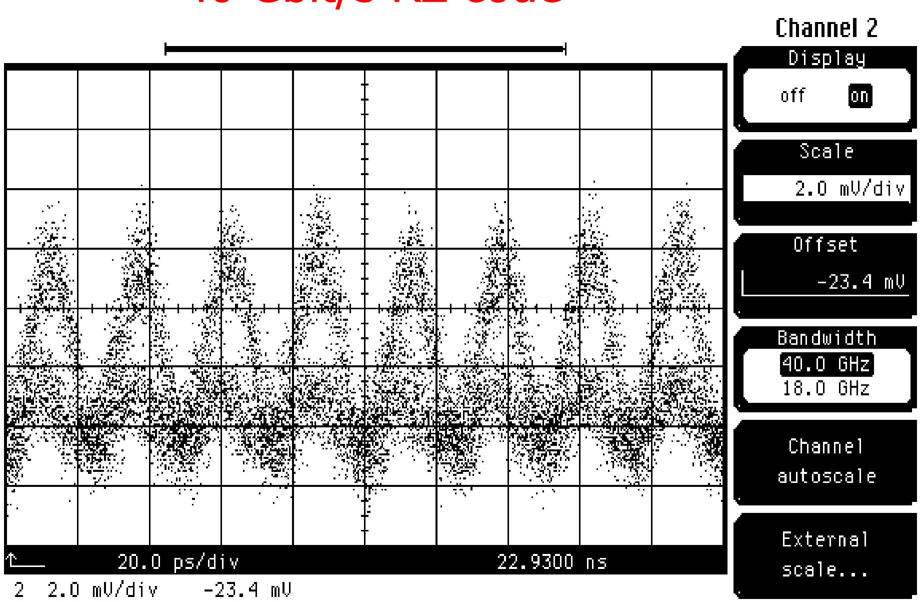
Example

- The transmission speed for optical fiber telecommunications
  - American standard: SONET (synchronous optical network).
  - International standard: SDH (synchronous digital hierarchy).

    bit rate for OC-768 (STM-256)=39.813 Gbit/s ≈ 40Gbit/s,

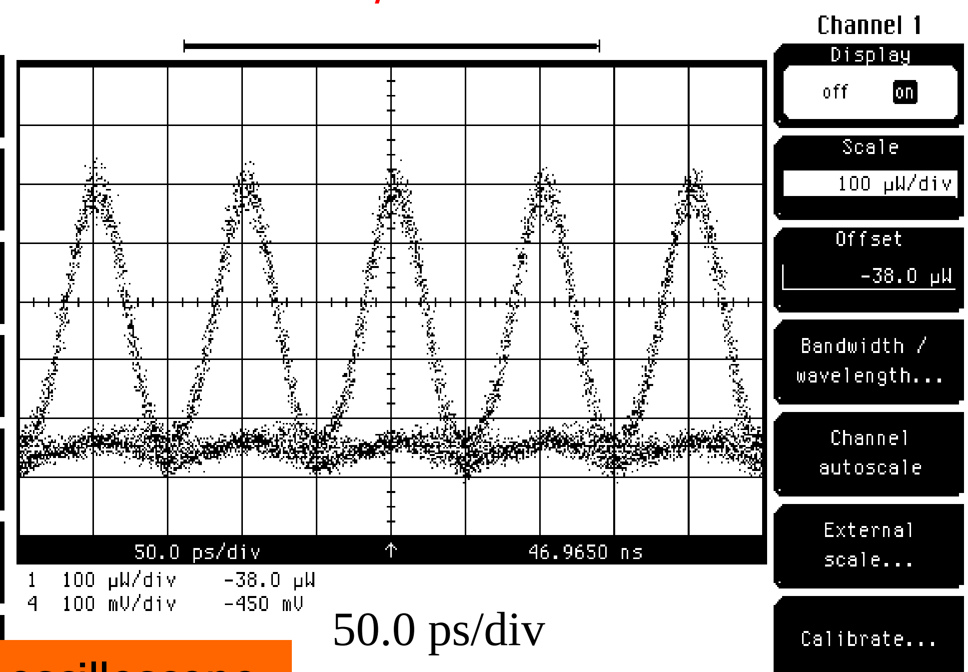
    the bit period $T_B \approx 25$ ps

40 Gbit/s RZ code



20.0 ps/div

10 Gbit/s RZ code



50.0 ps/div

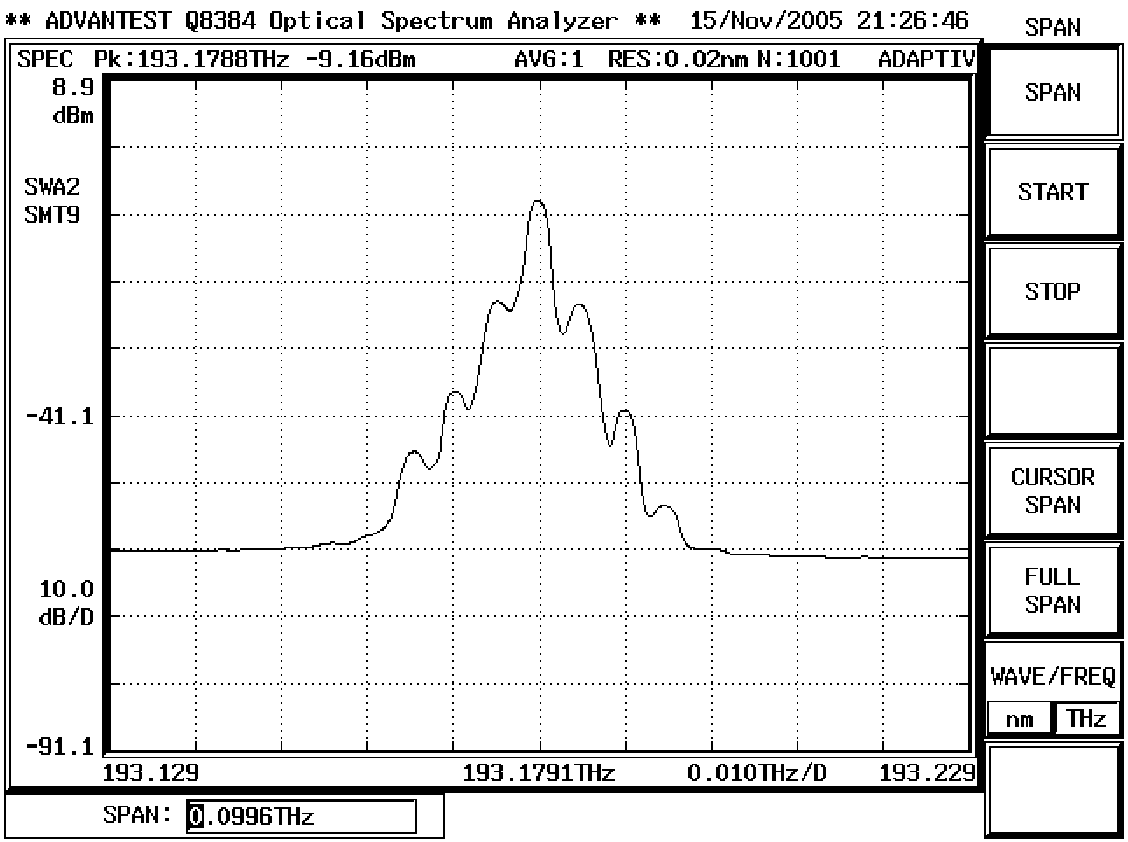
The screens of an oscilloscope

Example

- The optical spectrum for a semiconductor laser
  - Central frequency: 193.1788THz

$$\lambda = \frac{c}{f} = \frac{2.998\times10^{8}\,\mathrm{m/s}}{193.2\times10^{12}\,/\mathrm{s}}$$

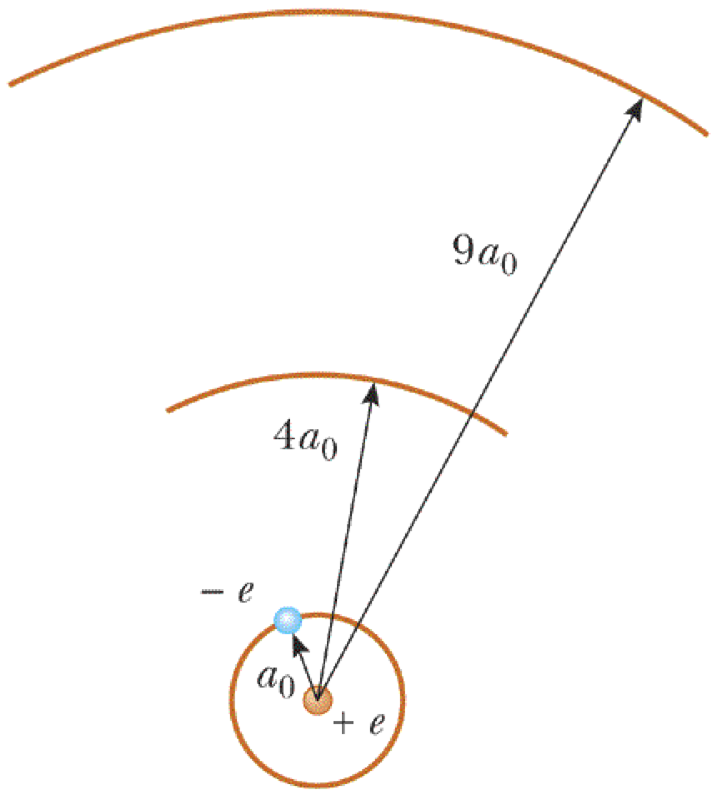
$$= 1.552\times10^{-6}\,\mathrm{m} = 1.552\,\mu\mathrm{m} = 1552\,\mathrm{nm}$$



The screen of an spectrum analyzer

- An older unit of length used for atomic scale: angstrom (Å)
  - $1\,\mathring{A} = 10^{-10}\,\text{m} = 0.1\,\text{nm}$
  - In Bohr theory of hydrogen, the orbits of the electron around the proton are quantized: $r_n = n^2 a_0$
  - The smallest radius a_0 is called the Bohr Radius.

$$a_0 = 0.529\,\mathring{A} = 0.0529\text{nm}$$



Dimensions and Dimensional analysis

All measurements reduce ultimately to the measurements of length, time and mass *in mechanics*. Length, time and mass specify the three primary dimensions（基本量纲）.

[L][T] [M]

The dimensions of a quantity refer to the combination of base quantities that comprise it.

That is: $\mathbf{dim}\,\boldsymbol{Q} = [\boldsymbol{Q}] = [L^q T^r M^s]$, where q, r, s can be positive, negative integer or fractional powers

For example :Force has dimensions of $[ML/T^2]$

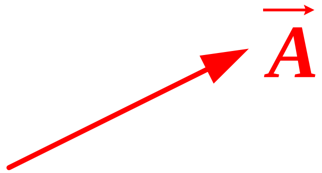
Any equation must be dimensionally consistent, that is, the dimensions on both sides of an equation must be the same.

Dimension analysis: Check the correctness of physical equation.

Special case: dimensionless.

§ 4 Vectors p. 45-51

- Vector: has both magnitude and direction
  - Graphical descriptions (using an arrow).
  - Component descriptions.



$$\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k}$$

Component A_x—the projection of $\vec{A}$ along the x axis.

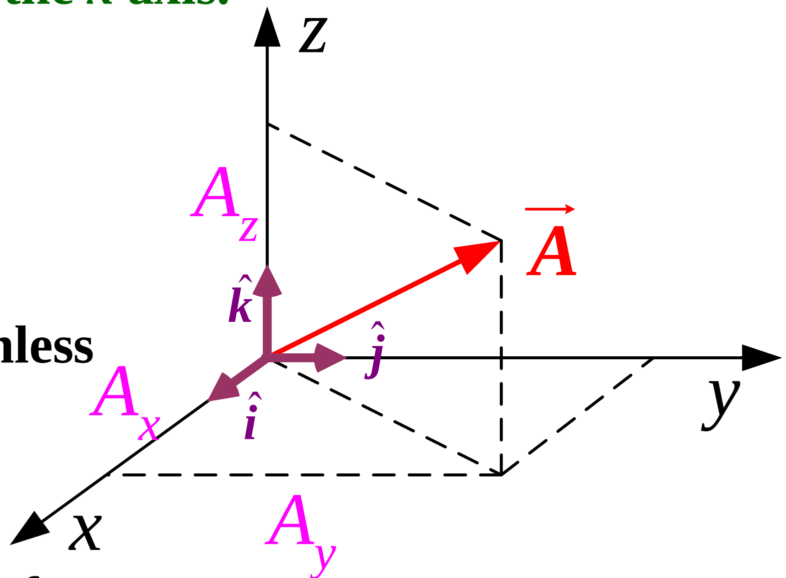
$A_x = A\cos\alpha$, $A_y = A\cos\beta$, $A_z = A\cos\gamma$

Magnitude of $\vec{A}$

$$A = |\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

Direction of $\vec{A}$ — unit vector — dimensionless

$$\hat{A} = \frac{\vec{A}}{|\vec{A}|}$$



$\hat{i}, \hat{j}, \hat{k}$ **are the unit vector in direction of x, y, z**

Vector Addition

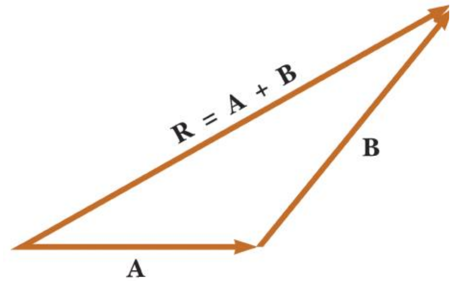
- Vector Addition
  - Graphical descriptions.

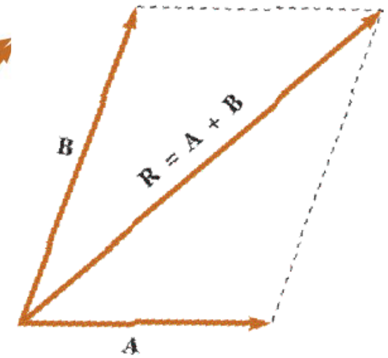
    triangle method of addition:

    ---place the tail of the second at the head (or tip) of the first.

    parallelogram rule of addition:

    ---the tails of two are together.

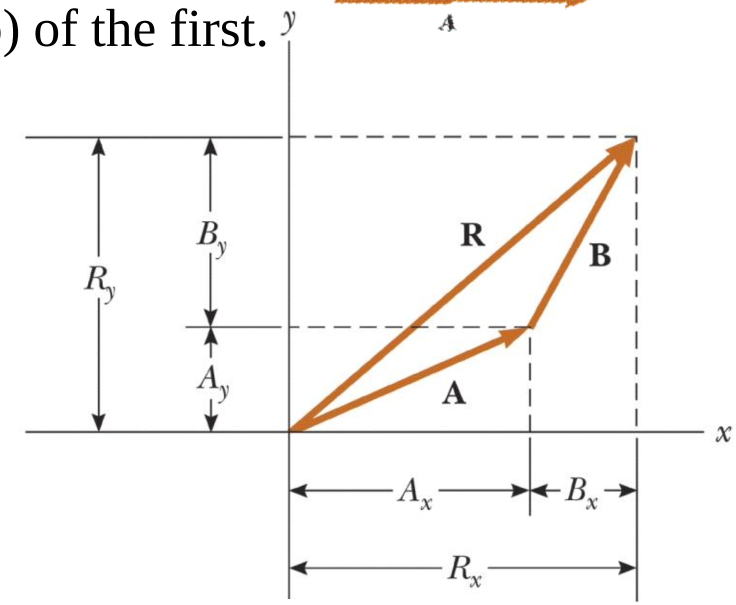




  - Component descriptions.

$$\vec{R} = \vec{A} + \vec{B}$$

$$= (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j} + (A_z + B_z)\hat{k}$$

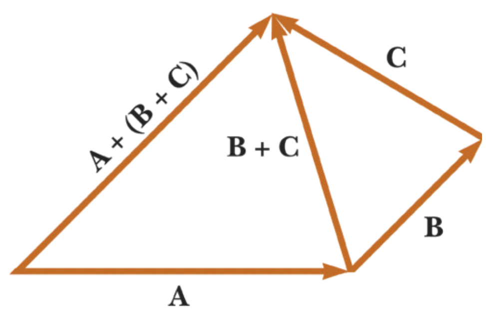


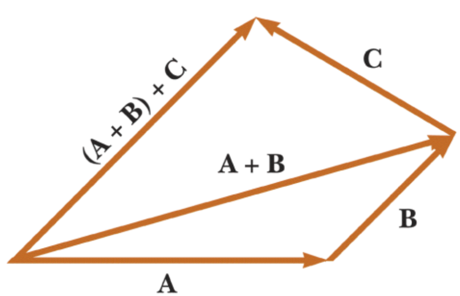
  - Commutation law of addition:

$$\vec{A} + \vec{B} = \vec{B} + \vec{A}$$

  - Association law of addition:

$$\vec{A} + (\vec{B} + \vec{C}) = (\vec{A} + \vec{B}) + \vec{C}$$

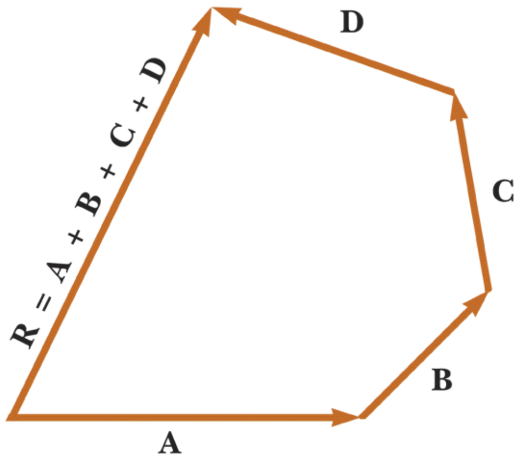




Vector Addition and Subtraction

- Addition of many vectors:

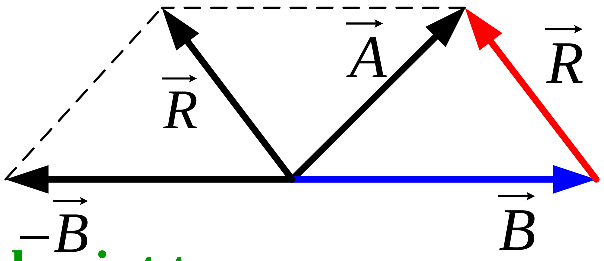
  All the vectors are placed with tail to tip, The resultant vector is the vector drawn from the tail of the first to the tip of the last



- Subtraction of Vectors
  - Graphical descriptions.

    $$\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$$

    Resultant vector tail at the second and point to the first.



  - Component descriptions.

$$\vec{A} - \vec{B} = (A_x - B_x)\hat{i} + (A_y - B_y)\hat{j} + (A_z - B_z)\hat{k}$$

Multiplying a Vector by a Vector

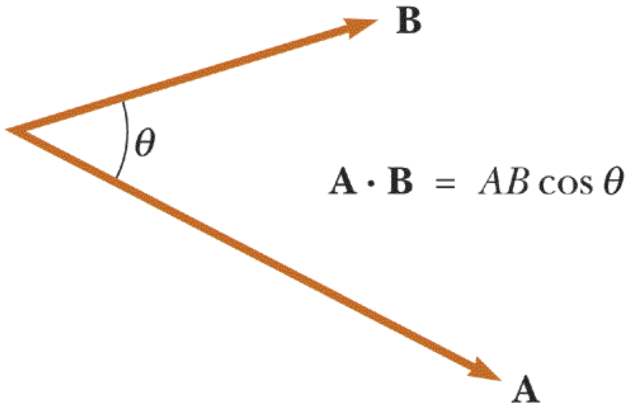
(1)The Scalar (Dot) Product of Two Vectors:

Definition:

$$\vec{A}\cdot\vec{B}=C\quad\begin{cases} C = A_xB_x + A_yB_y + A_zB_z \\ C = AB\cos\theta \end{cases}$$

$$\vec{A}\cdot\vec{B}=\vec{B}\cdot\vec{A}$$

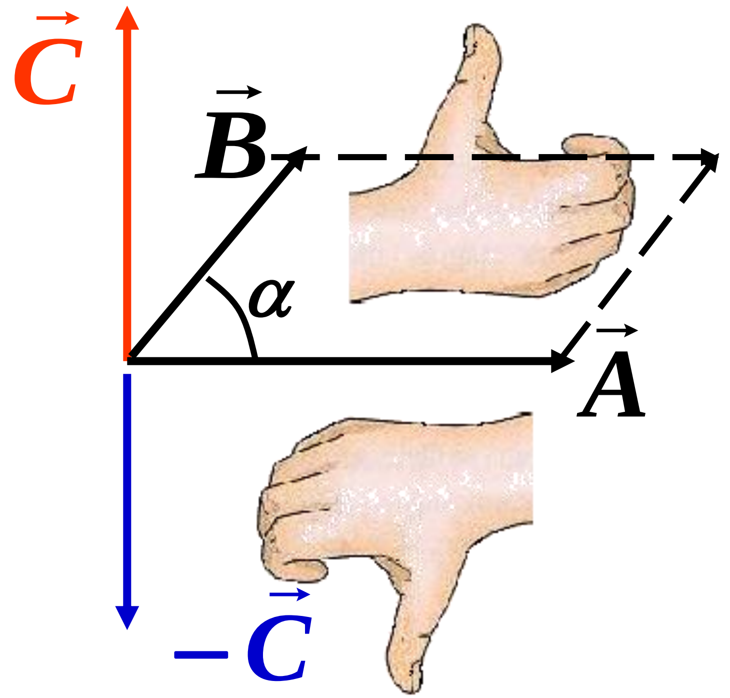
$$\vec{A}\cdot(\vec{B}+\vec{C})=\vec{A}\cdot\vec{B}+\vec{A}\cdot\vec{C}$$



(2) The Vector (Cross) Product of Two Vectors

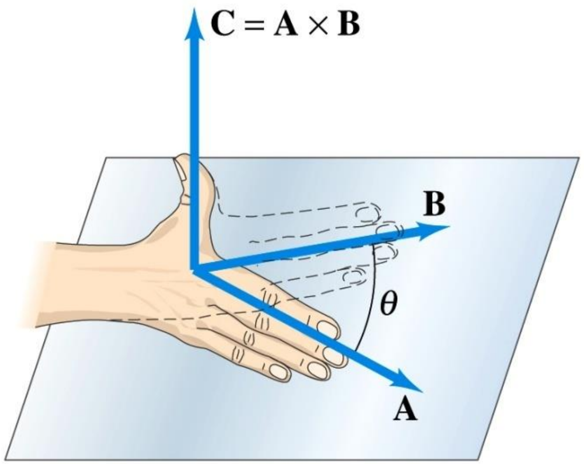
$$\vec{A}\times\vec{B}=\vec{C}\begin{cases}\vec{C}=(A_yB_z-A_zB_y)\hat{i}+(A_zB_x-A_xB_z)\hat{j}\\ \quad +(A_xB_y-A_yB_x)\hat{k}\\ \left|\vec{A}\times\vec{B}\right|=AB\sin\alpha,\\ \text{Direction is as the figure showing}\end{cases}$$

$$\vec{B}\times\vec{A}=-\vec{A}\times\vec{B}=-\vec{C}$$



The Vector Cross Product

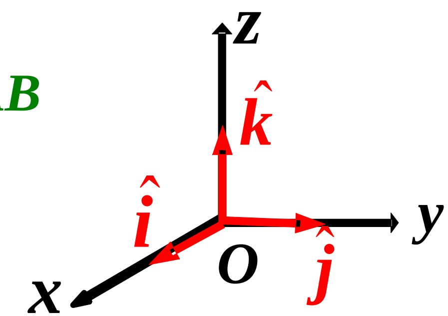
- The Vector Products of Two Vectors (Also Cross Product)
  - Definition. $\boxed{\vec{C} = \vec{A} \times \vec{B}}$



    - Magnitude: $C = |\vec{C}| = AB\sin\theta$
    - Direction: perpendicular to the plane formed by $\vec{A}$ and $\vec{B}$ in a direction determined by the right-hand rule.
  - Special cases
    - If $\vec{A}$ is parallel to $\vec{B}$ (θ=0° or 180°), then $\vec{A} \times \vec{B} = 0$; it follows that $\vec{A} \times \vec{A} = 0$
    - If $\vec{A}$ is perpendicular to $\vec{B}$, then $|\vec{A} \times \vec{B}| = AB$
    - For unit vectors

$$\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0,$$

$$\hat{i} \times \hat{j} = \hat{k},\ \ \hat{j} \times \hat{k} = \hat{i},\ \ \hat{k} \times \hat{i} = \hat{j}$$



The derivation of a vector

$$\boxed{\frac{d\vec{C}}{dt} = \frac{d(\mu\vec{A})}{dt} = \frac{d\mu}{dt}\vec{A} + \mu\frac{d\vec{A}}{dt}}$$

$$\boxed{\frac{dC}{dt} = \frac{d(\vec{A}\cdot\vec{B})}{dt} = \frac{d\vec{A}}{dt}\cdot\vec{B} + \vec{A}\cdot\frac{d\vec{B}}{dt}}$$

$$\boxed{\frac{d\vec{C}}{dt} = \frac{d(\vec{A}\times\vec{B})}{dt} = \frac{d\vec{A}}{dt}\times\vec{B} + \vec{A}\times\frac{d\vec{B}}{dt}}$$

作业

P13-14

Question: 20、36、37