Evaluation (Corrected)

- Homework (25%)
- First midterm (25%)
- Second midterm (25%)
- Final (25%)

Course announcement

- If you need to extra selection(加簽) in this course, please apply for additional enrollment request via university’s system by 5PM, 2022/09/16(Fri.). Your enrollment or not will be decided at 5PM on 9/16. Any late additional enrollment request will be rejected.

GENERAL PHYSICS B (1)
FUNDAMENTAL TOOLS

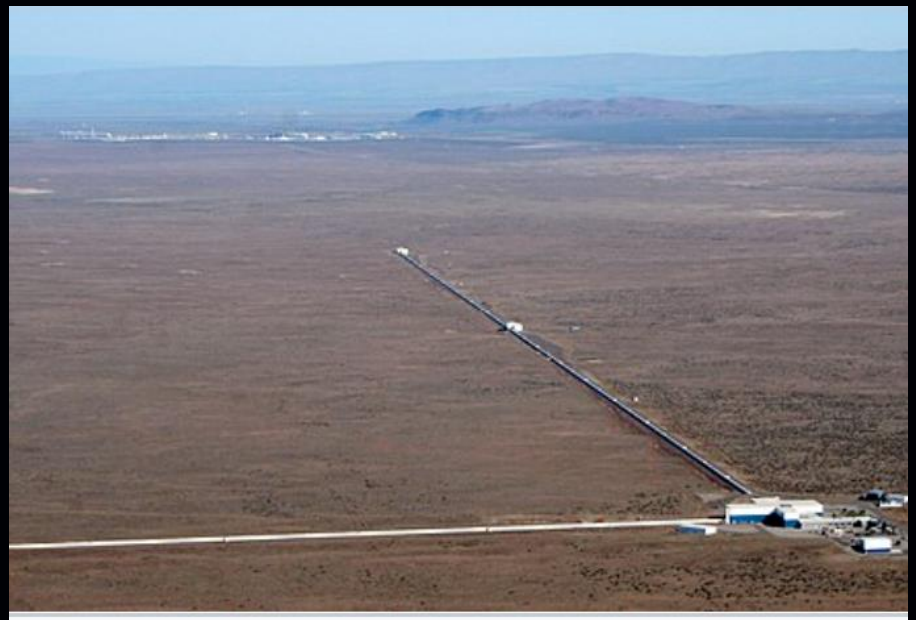
Vector & Calculus

2022/09/16

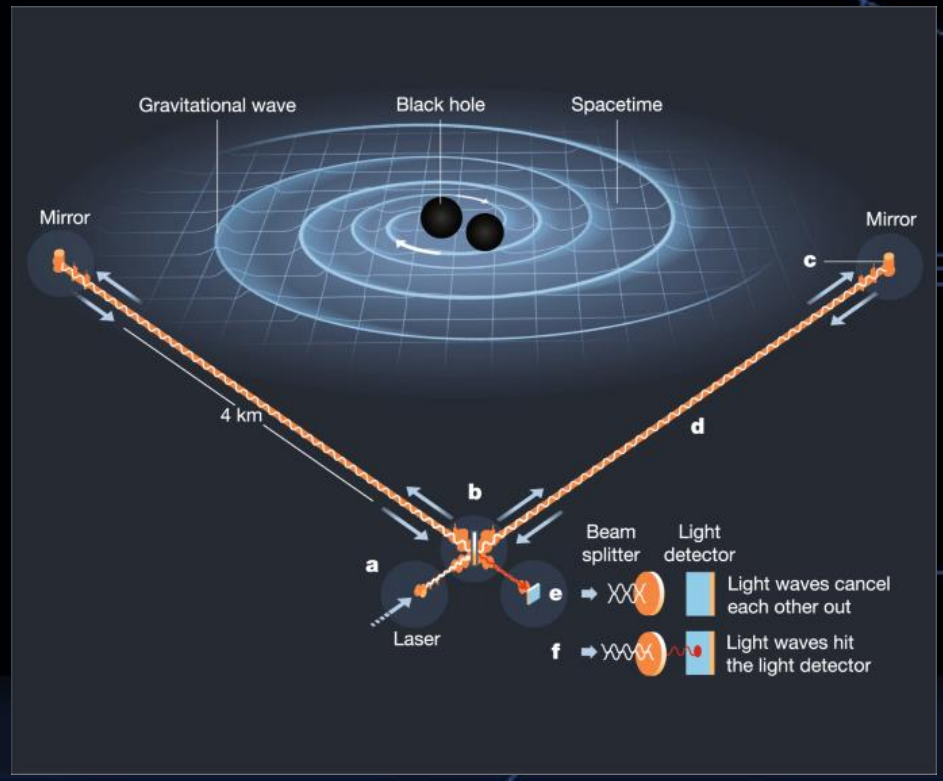
Foundation of Physics – Measurement & Units

- Physics is based on measurement and comparison of physical quantities. The main goal of physicists is finding out the relationships between physical quantities.
- We measure each physical quantity in its own units, by comparison with a standard. The unit is a unique name we assign to measures of that quantity

Laser Interferometer Gravitational-Wave Observatory (LIGO)



LIGO Hanford Observatory



Can measure change of length in 10^{-18} meter!

International System of Units – SI Units

Quantity	Unit Name	Unit Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg

Physical quantities with/without direction

- Quantities that are described by a **magnitude** but **no direction** are **scalars**.

Examples: number of students, time, temperature, and mass.

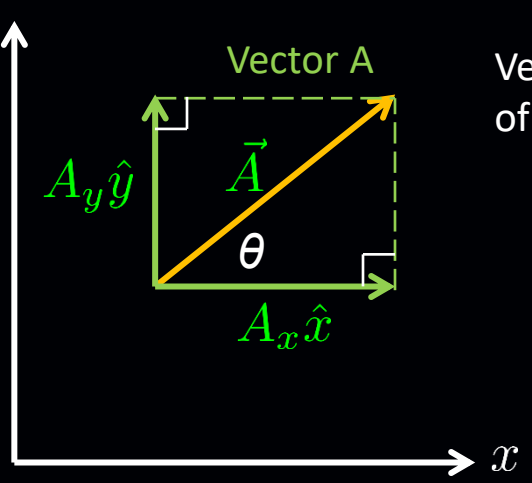
- Quantities that are described by a **magnitude** and a **direction** are **vectors**.

Examples: displacement, velocity, acceleration, and mass flow.

Fundamental properties of vectors

In the 2D Cartesian coordinate, we have x-axis and y-axis.

Unit vectors are represented by $\hat{x}$ and $\hat{y}$ (sometimes $\hat{i}$ and $\hat{j}$)



Vector A is expressed as a vector sum of the x and y vector components

$$\vec{A} = A_x\hat{x} + A_y\hat{y}$$

The magnitude of vector A is

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

The rectangular components of $\vec{A}$ are

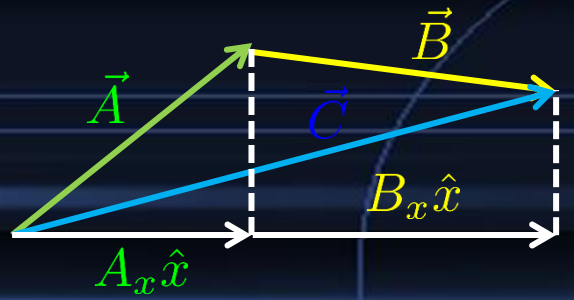
$$A_x = A\cos\theta \qquad A_y = A\sin\theta$$

The angle θ is related to A_x and A_y by

$$\frac{A_y}{A_x} = \frac{A\sin\theta}{A\cos\theta} = \tan\theta$$

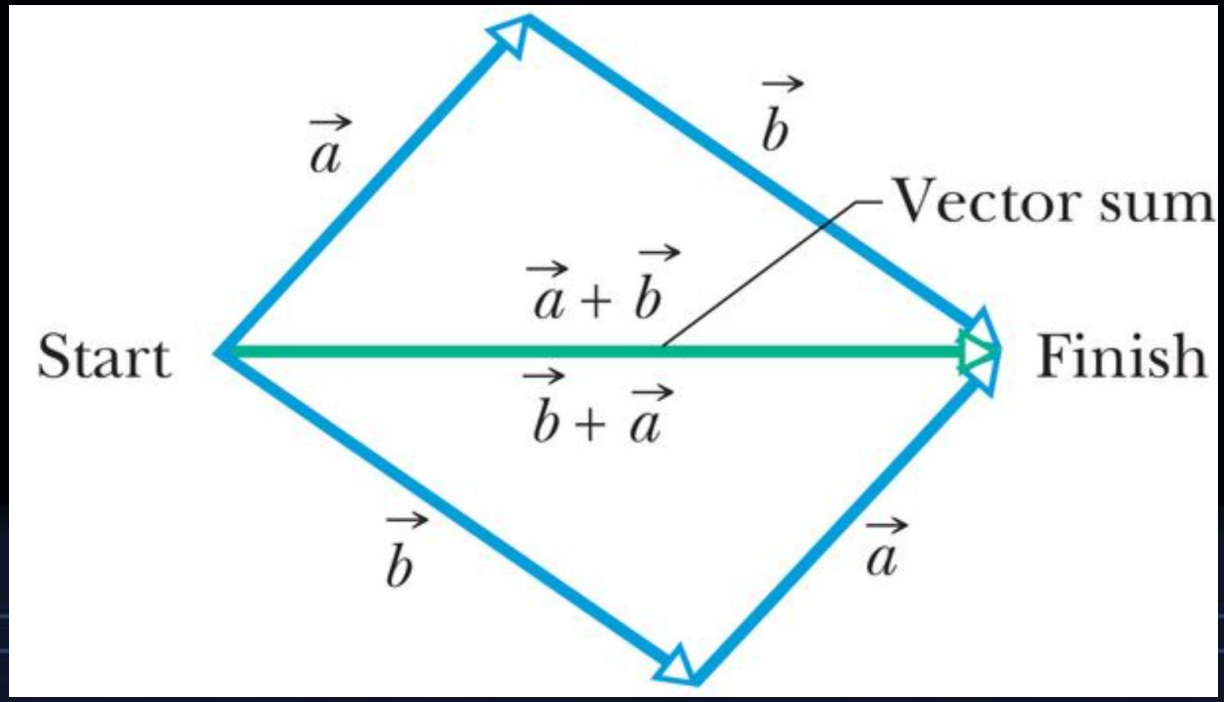
Vector addition:

$$\begin{aligned}\vec{A} + \vec{B} &= \vec{C} \\ &= (A_x\hat{x} + A_y\hat{y}) + (B_x\hat{x} + B_y\hat{y}) \\ &= (A_x + B_x)\,\hat{x} + (A_y + B_y)\,\hat{y}\end{aligned}$$



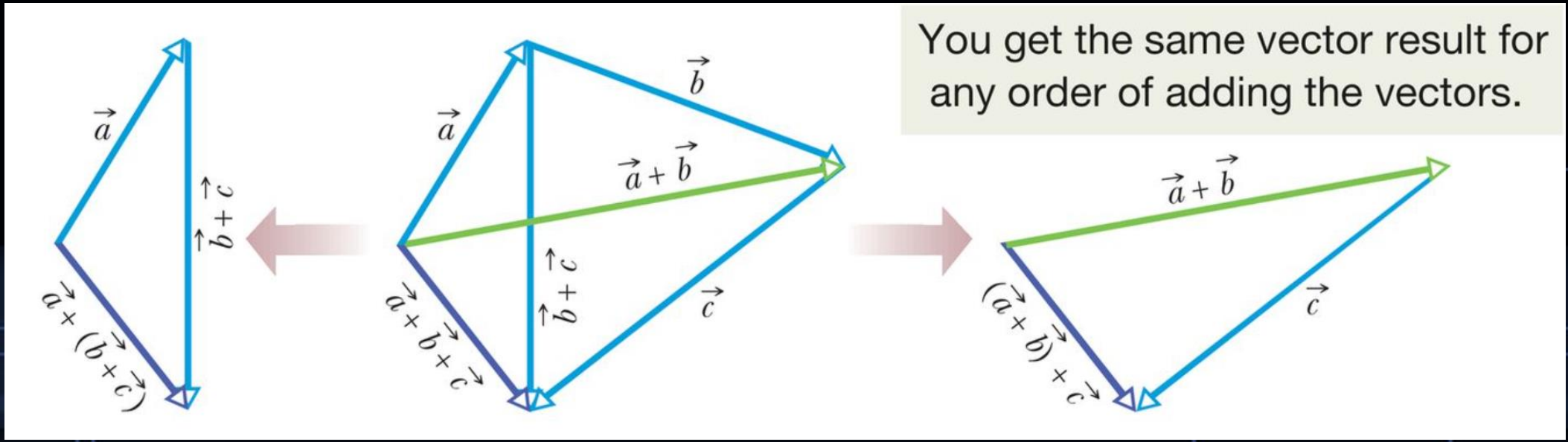
Addition rules of vectors

- Commutative law $\vec{a} + \vec{b} = \vec{b} + \vec{a}$



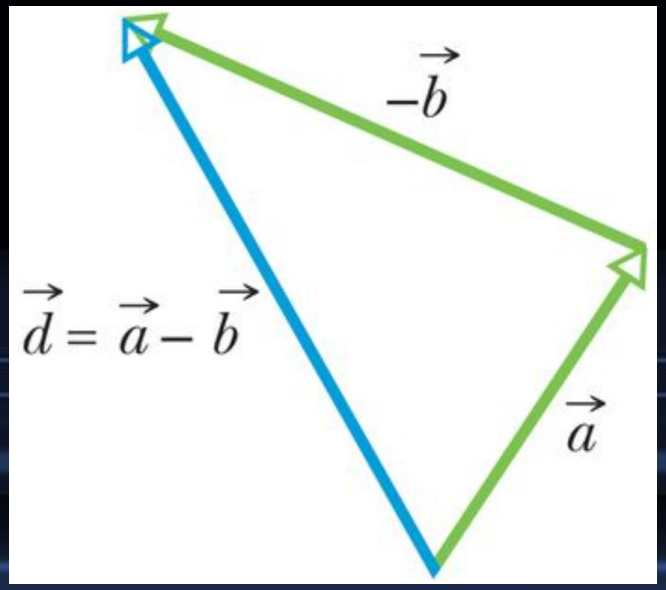
Addition rules of vectors

- Commutative law $\vec{a} + \vec{b} = \vec{b} + \vec{a}$
- Associative law $(\vec{a} + \vec{b}) + \vec{c} = \vec{a} + (\vec{b} + \vec{c})$



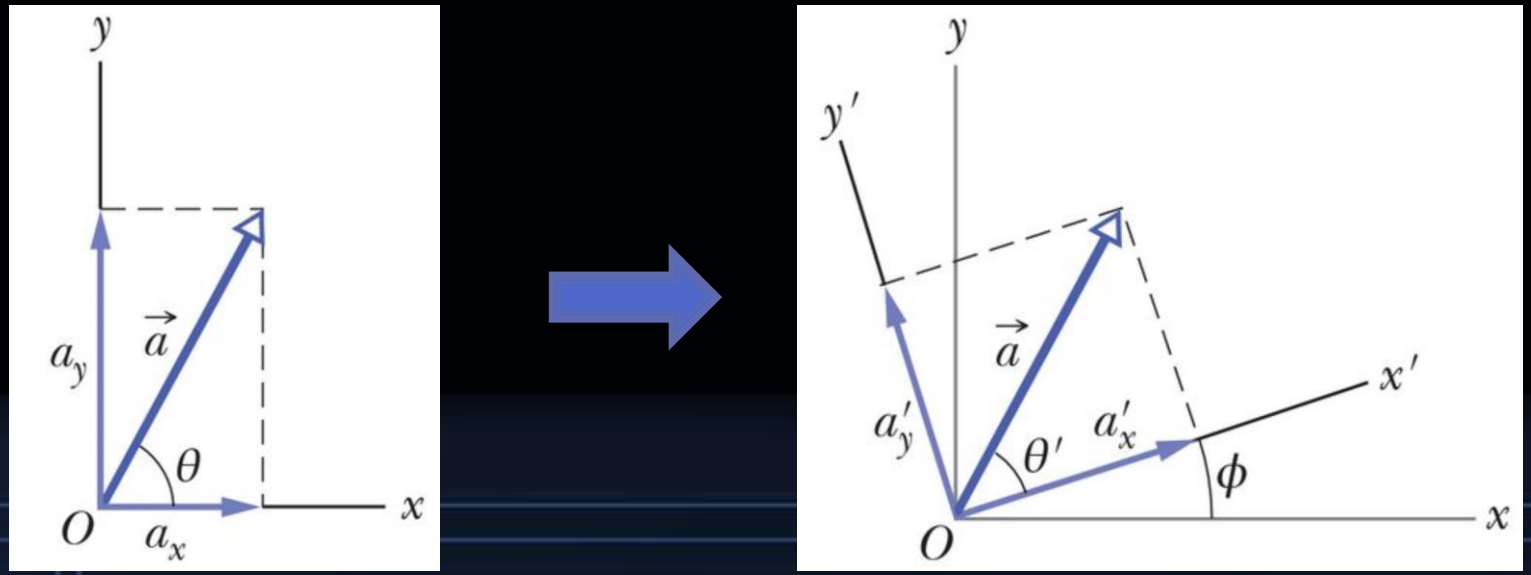
Addition rules of vectors

- Commutative law $\vec{a} + \vec{b} = \vec{b} + \vec{a}$
- Associative law $(\vec{a} + \vec{b}) + \vec{c} = \vec{a} + (\vec{b} + \vec{c})$
- Subtraction of vector $\vec{d} = \vec{a} - \vec{b} = \vec{a} + (-\vec{b})$



Rotation of coordinates

- Rotation of the coordinates changes components but not the vector



$$\sqrt{a_x^2 + a_y^2} = \sqrt{a'^2_x + a'^2_y}$$

$$\theta = \theta' + \phi$$

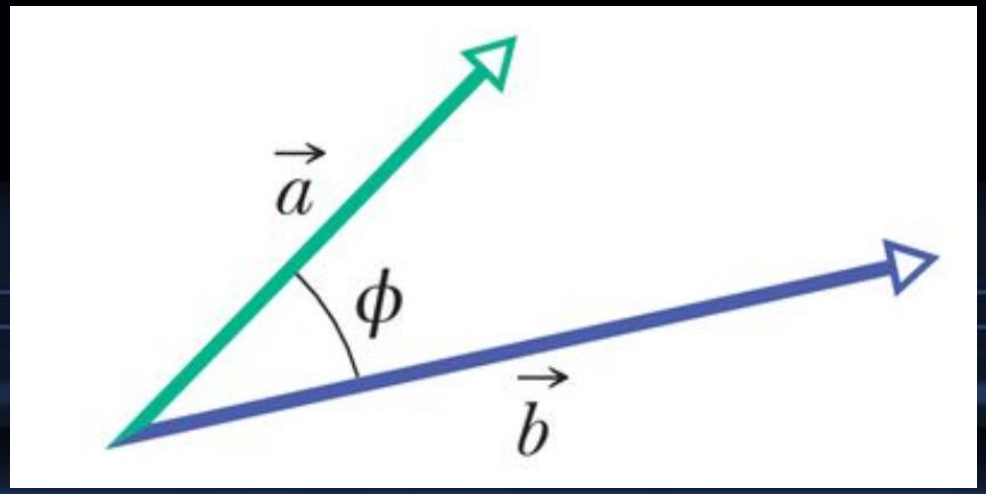
Multiplication of vectors

- Multiply a vector by a scalar: $s\vec{a} = sa_x\hat{x} + sa_y\hat{y}$

Multiplication of vectors

- Multiply a vector by a scalar: $s\vec{a} = sa_x\hat{x} + sa_y\hat{y}$
- Multiply a vector by a vector:
  - Inner product(dot product): $\vec{a} \cdot \vec{b} = ab\ cos\phi = a_x b_x + a_y b_y$

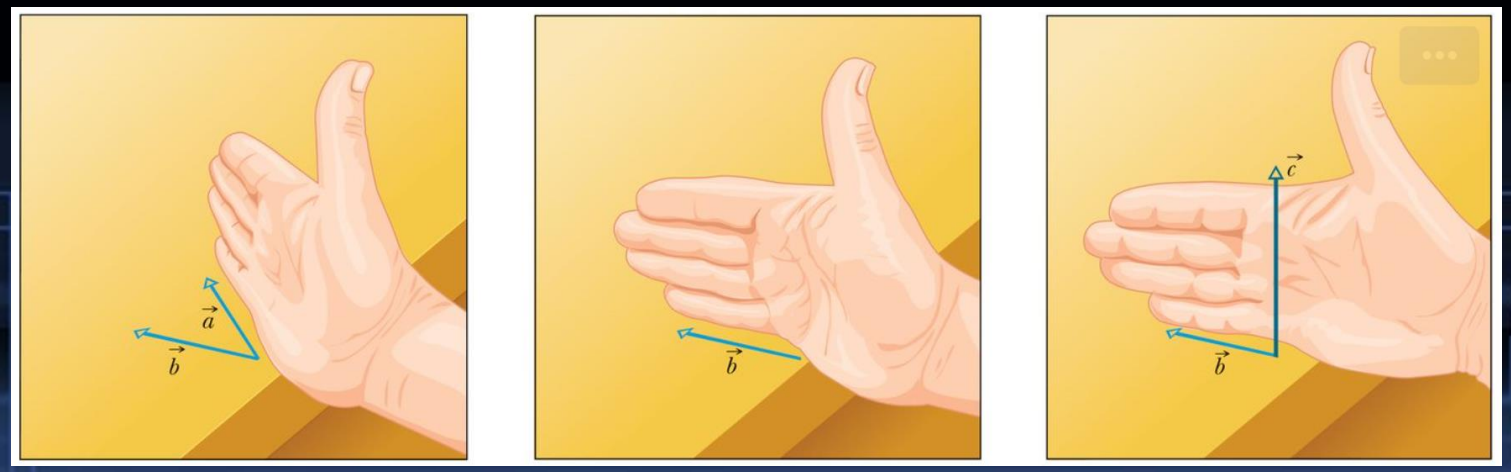
(result in a scalar)



Multiplication of vectors

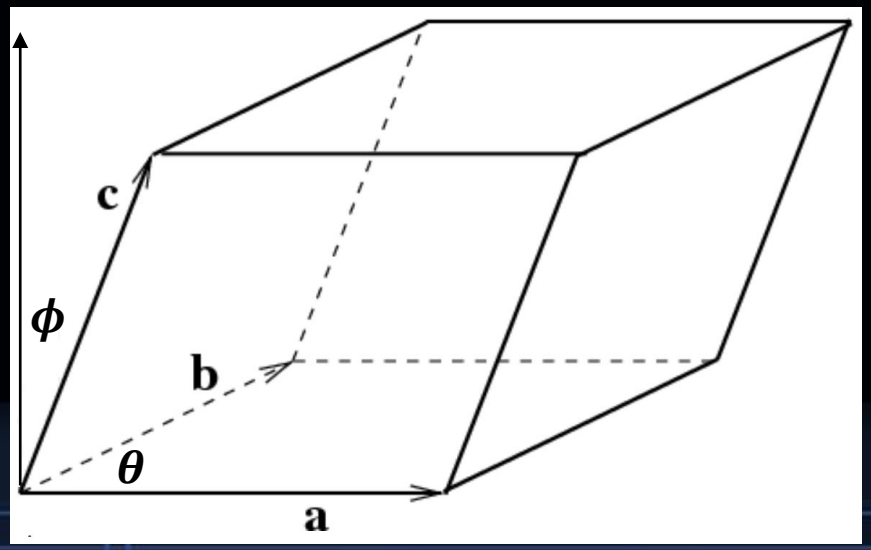
- Multiply a vector by a scalar: $s\vec{a} = sa_x\hat{x} + sa_y\hat{y}$
- Multiply a vector by a vector:
  - Inner product(dot product): $\vec{a} \cdot \vec{b} = ab\ cos\phi = a_x b_x + a_y b_y$
  - vector product(cross product): (result in a vector)

$$\vec{a} \times \vec{b} = (a_y b_z - a_z b_y)\hat{x} + (a_z b_x - a_x b_z)\hat{y} + (a_x b_y - a_y b_x)\hat{z}$$



Example of using vectors multiplication

- What is the volume of a parallelepiped that span by three vectors $\vec{a}$, $\vec{b}$, and $\vec{c}$?



The area of bottom parallelogram:

$$ab\ sin\theta$$

The height:

$$c\ cos\phi$$

The volume:

$$abc\ cos\phi\ cos\theta = (\vec{a} \times \vec{b}) \cdot \vec{c}$$

Questions?

Foundation of Physics – Measurement & Units

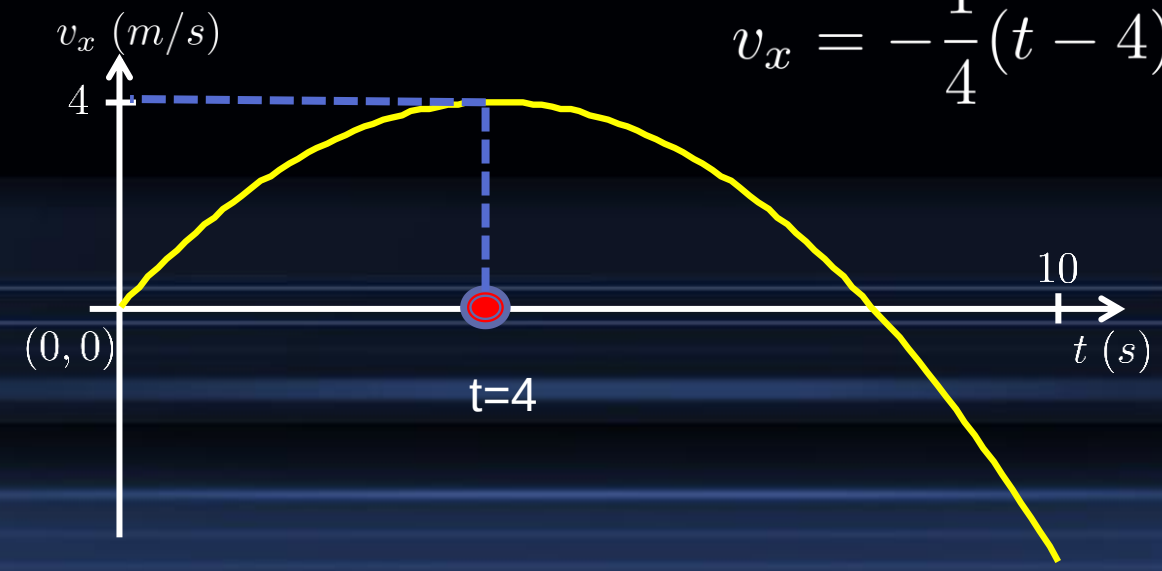
- Physics is based on measurement and comparison of physical quantities. The main goal of physicists is finding out the relationships between physical quantities.
- The relationships may be in the derivative or integral of a physical quantities respect to some other quantities.

Concept of continuous function

- We often can find one physical quantity as a continuous function of the other quantity. This express a mapping relation between one physical quantity to the other one.

  Example: velocity as function of time.

$$v_x = -\frac{1}{4}(t-4)^2 + 4$$



$(y_2 - y_1) = m(x_2 - x_1)$

Derivative and infinitesimal Change

The acceleration is the measure of change in velocity in an infinitesimal time,

$$a_x = \frac{dv_x}{dt}$$

Or we can say that, in an infinitesimal time, the change in velocity is related to the acceleration

$$dv_x = a_x dt$$

Let's take a closer look at it.

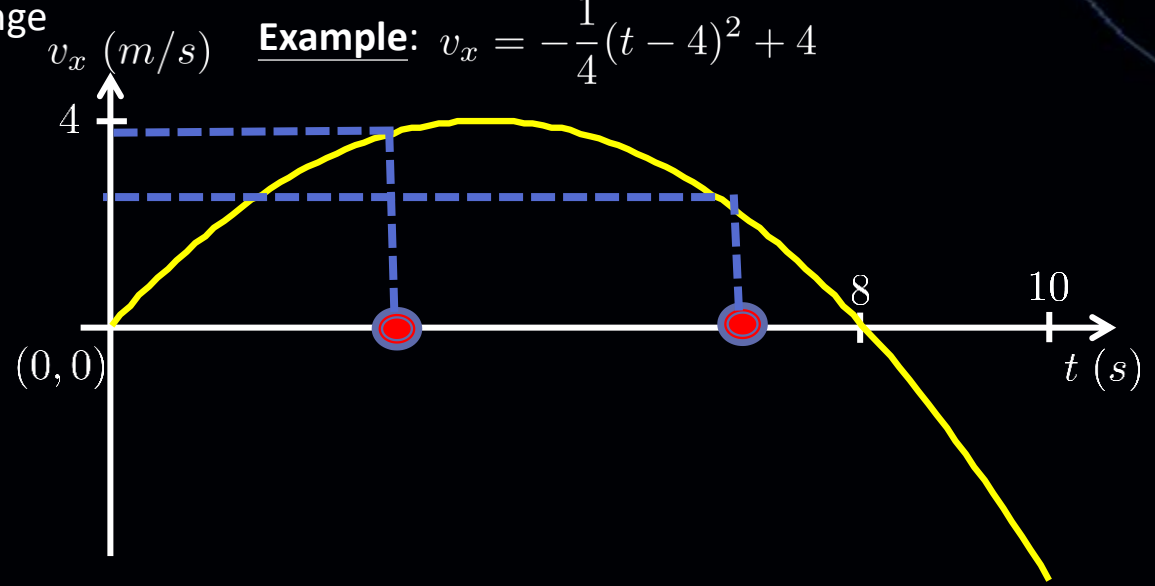
A smooth function plotted over a very small window of
time would look like a straight line. Why?

Let's say we're interested the behavior of the function near $t = t_0$. We know the value of this function at t_0,

$$v_x(t_0) = -\frac{1}{4}(t_0 - 4)^2 + 4$$

The slope of the tangent at $t = t_0$ is

$$\left.\frac{dv_x}{dt}\right|_{t=t_0} = \lim_{\Delta t \to 0} \left.\frac{\Delta v_x}{\Delta t}\right|_{t=t_0} = -\frac{t_0 - 4}{2}$$



Example: $v_x = -\frac{1}{4}(t-4)^2 + 4$

How about the value of this function at $t_0 + \Delta t$?

$$\begin{aligned} v_x(t_0 + \Delta t) &= -\frac{1}{4}(t_0 + \Delta t - 4)^2 + 4 \\ &= -\frac{1}{4}\left[(t_0 - 4)^2 + 2(t_0 - 4)\Delta t + \Delta t^2\right] + 4 \\ &= v_x(t_0) - \frac{1}{4}\left[2(t_0 - 4)\Delta t + \Delta t^2\right] \end{aligned}$$

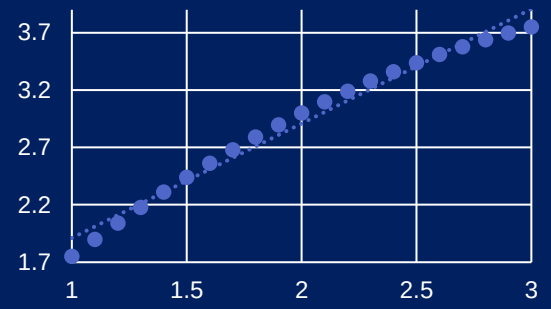
If Δt is really small, so that Δt^2 is negligible. We obtain

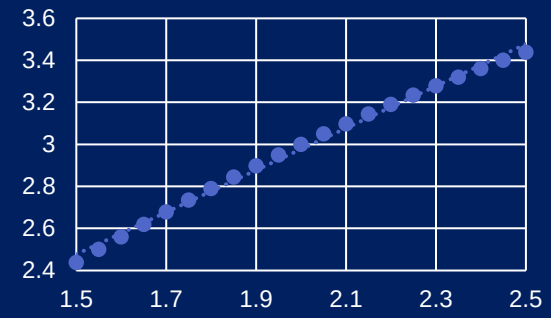
$$v_x(t_0 + \Delta t) \approx v_x(t_0) - \frac{(t_0 - 4)}{2}\Delta t$$ which is a line

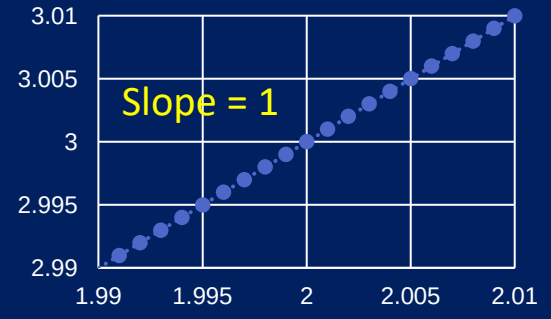
$(y_2 - y_1) = m(x_2 - x_1)$

tive and infinitesimal Change

For example, let's zoom in the curve around







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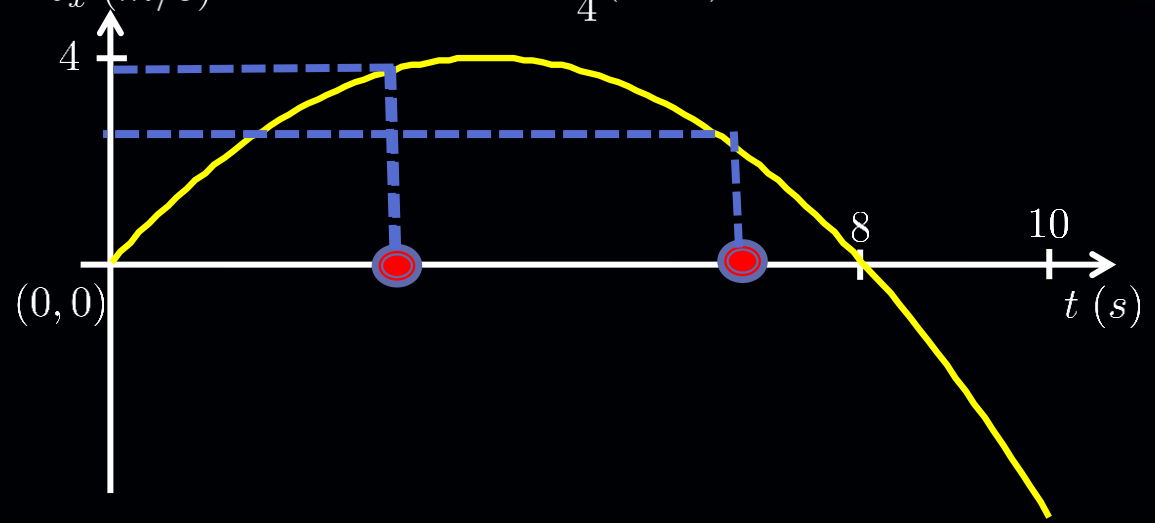
$v_x\ (m/s)$ **Example**: $v_x = -\frac{1}{4}(t-4)^2 + 4$



How about the value of this function at $t_0 + \Delta t$?

$$v_x(t_0 + \Delta t) = -\frac{1}{4}(t_0 + \Delta t - 4)^2 + 4$$
$$= -\frac{1}{4}\left[(t_0 - 4)^2 + 2(t_0 - 4)\Delta t + \Delta t^2\right] + 4$$
$$= v_x(t_0) - \frac{1}{4}\left[2(t_0 - 4)\Delta t + \Delta t^2\right]$$

If Δt is really small, so that Δt^2 is negligible. We obtain

$$v_x(t_0 + \Delta t) \approx v_x(t_0) - \frac{(t_0 - 4)}{2}\Delta t$$ which is a line

Subscript i denotes initial and subscript f denotes final.

The acceleration is the measure of change in velocity in an infinitesimal time,

$$a_x = \frac{dv_x}{dt}$$

Or we can say that, in an infinitesimal time, the change in velocity is related to the acceleration

$$dv_x = a_x dt$$

Therefore, we can obtain the change in velocity within a **finite** period of time if we know how acceleration changes with time.

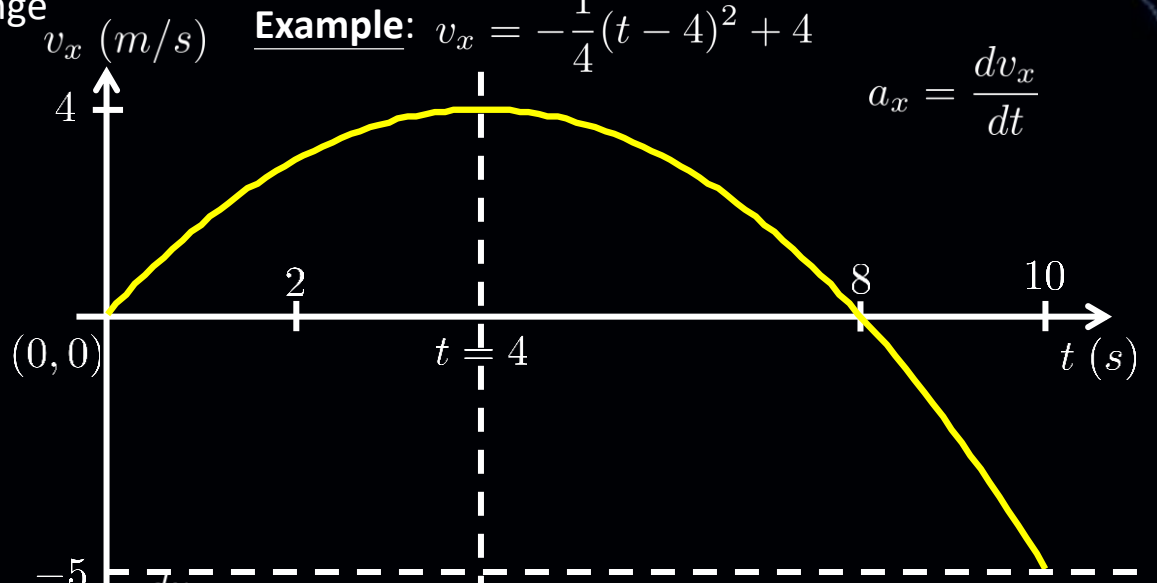
$$\int_{(v_x)_i}^{(v_x)_f} dv_x = \int_{t_i}^{t_f} a_x(t)dt$$

$$(v_x)_f - (v_x)_i = \int_{t_i}^{t_f} a_x(t)dt$$

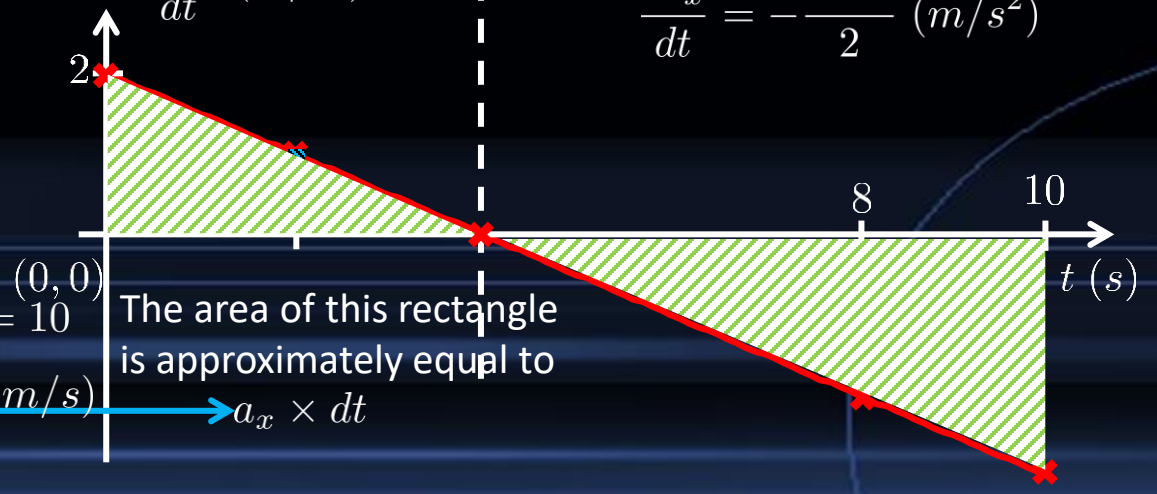
For example, Let's take $t_i = 0$ and $t_f = 10$

$$(v_x)_f - (v_x)_i = \frac{2 \times 4}{2} - \frac{3 \times 6}{2} = -5 \ (m/s)$$

Example: $v_x = -\frac{1}{4}(t-4)^2 + 4$



$a_x = \frac{dv_x}{dt}$



The area of this rectangle is approximately equal to $a_x \times dt$

Frequently used derivatives

Useful derivatives:

$$\frac{dx^n}{dx} = nx^{n-1}$$

$$\frac{d\sin x}{dx} = \cos x$$

$$\frac{d\cos x}{dx} = -\sin x$$

$$\frac{d\tan x}{dx} = \sec^2 x$$

$$\frac{d\cot x}{dx} = -\csc^2 x$$

$$\frac{de^x}{dx} = e^x$$

Exponential function
(指數函數)

$$e \approx 2.718281828$$

Euler's number

$$\ln(x) \equiv \log_e(x)$$

$$\frac{d\ln(x)}{dx} = \frac{1}{x}$$

Take Home message

- We use vectors to describe physical quantities with magnitude and direction.
- Vectors can have addition and multiplication rules
- A continuous function can map one physical quantity to another one.
- Derivative => slope of a function
- Integration => area under a function

Questions?

Backup

GENERAL PHYSICS B (1) (11110PHYS113303)

3 Credits

Lecturer: Yen-Hsiang Lin 林晏詳
Office: Physics Building R520
Email: yhlin@phys.nthu.edu.tw

Course Information

- Join the class by:

a. Face-to-face class(Main): 8:30~10:00AM Tuesday and Friday @GEN IV 224 (with facial mask and social distance)

b. Realtime online via Microsoft Team https://teams.live.com/meet/9570955571789

c. Recorded google meeting video on eLearn https://elearn.nthu.edu.tw/

Additional enrollment (加簽)

Due to the classroom space limitation of 190 people, we can only offer for 30 more students for enrolling in this course. The priority for the enrollment is following:

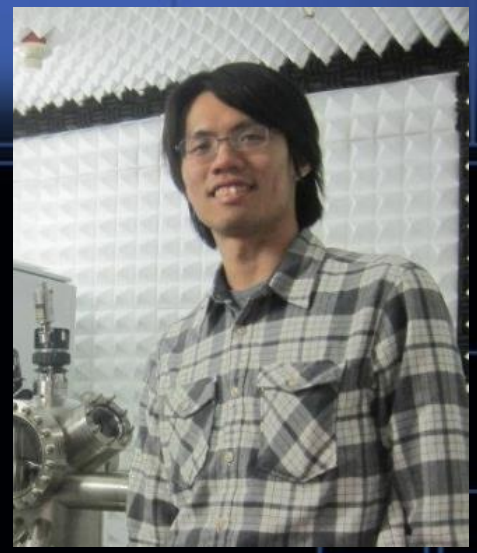
1. Senior international students
2. Senior students
3. Freshman international students
4. Freshman

If you are interested in this course, please apply for additional enrollment request via university's system by 5PM, 2022/09/16(Fri.). Your enrollment or not will be decided at 5PM on 9/16. Any late additional enrollment request will be rejected.

Course Format

- Join This course will be mainly taught by lecturing with power point slides. Power point slides is easier for remote class and recording.
- All the slides will be posted on eLearn Platform. Please do not spread out without permission.
- 8:30~10:00AM without breaking
- Note that this course will be given in English.

Yen-Hsiang Lin 林晏詳
Assistant Professor
Department of Physics,
National Tsinghua University
Email: yhlin@phys.nthu.edu.tw



2011 Ph.D Physics, University of Minnesota
2011~2014 Postdoc Researcher, University of Michigan
2011~2020 Postdoc Researcher, University of Maryland
2020~current Assistant Professor, National Tsinghua University

Research Interests

- Condensed matter physics experimentalist
- Superconducting qubits and quantum information
- Transport and RF properties of low dimensional superconductor
- Nano-scale electronic and thermoelectric semiconductor materials

Course Content

- Fundamental Tools
- Dynamics systems (動力學系統)
  - Kinetics
  - Newton's Laws
  - Energy
  - Many Particles Motion and Rotation
  - Oscillation and Waves
  - Fluid motion
- Thermodynamics (熱力學)
  - Heat, Work, and the first law of thermal dynamics
  - Entropy and the second law of thermal dynamics

Course Calendar I

Week	Date	Content
1	9/13(Tue.)	**Course Information** **Fundamental Tools**: measurement & unit
1	9/16(Fri.)	**Fundamental Tool:** vector & basic calculus
2	9/20(Tue.)	**Kinetics:** motion in 1D
2	9/23(Fri.)	**Kinetics:** motion in 2D and 3D
3	9/27(Tue.)	**Newton's law:** Newton's first and second law I
3	9/30(Fri.)	**Newton's law:** Newton's first and second law II (Homework 1)
4	10/4(Tue.)	**Newton's law:** Newton's third law
4	10/7(Fri.)	**Energy:** kinetic energy and work
5	10/11(Tue.)	**Energy:** potential energy and conservation of energy
5	10/14(Fri.)	**Gravity:** Law of gravity (Homework2)
6	10/18(Tue.)	**Gravity:** Gravitational energy and gravitational field
6	10/21(Fri.)	**Review I**
7	10/25(Tue.)	Mid Term 1
7	10/28(Fri.)	**Many Particles Motion and Rotation:** center of mass & liner momentum
8	11/1(Tue.)	**Many Particles Motion and Rotation:** rotation
8	11/4(Fri.)	**Many Particles Motion and Rotation:** torque & angular momentum

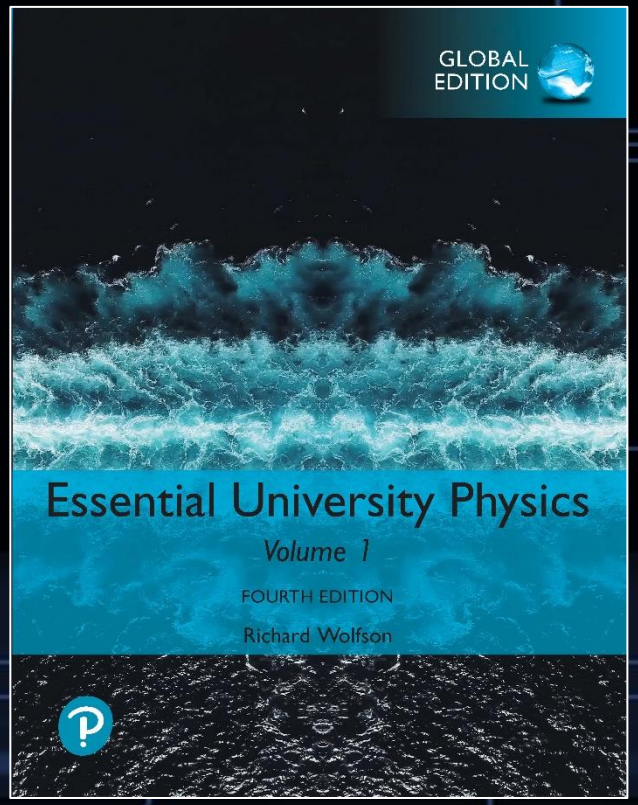
Course Calendar II

9	11/8(Tue.)	**Oscillation and Waves:** simple harmonic oscillation
9	11/11(Fri.)	**Oscillation and Waves:** damped and forced oscillation (Homework3)
10	11/15(Tue.)	**Oscillation and Waves:** description of waves
10	11/18(Fri.)	**Oscillation and Waves:** interference of waves
11	11/22(Tue.)	**Oscillation and Waves:** propagation of waves
11	11/25(Fri.)	**Fluid Motion:** Density, Pressure, and Hydrostatic Equilibrium (Homework4)
12	11/29(Tue.)	**Fluid Motion:** Fluid Dynamics and Application
12	12/2(Fri.)	**Review II**
13	12/6(Tue.)	Mid Term 2
13	12/9(Fri.)	**Temperature and Heat:** temperature, heat and thermal equilibrium
14	12/13(Tue.)	**Temperature and Heat:** Heat capacity, specific heat, and heat transfer
14	12/16(Fri.)	**Thermal Behavior of Matter:** ideal gases, and kinetic theory of ideal gas
15	12/20(Tue.)	**Thermal Behavior of Matter:** phase changes and thermal expansion
15	12/23(Fri.)	**The First Law of Thermal Dynamics:** 1st law of thermal dynamics
16	12/27(Tue.)	**The First Law of Thermal Dynamics:** Thermodynamic processes (Homework5)
16	12/30(Fri.)	**Entropy and the Second Law of Thermal Dynamics:** entropy
17	1/3(Tue.)	**Entropy and the Second Law of Thermal Dynamics:** engines and refrigerator
17	1/6(Fri.)	**Review III**
18	1/10(Tue.)	Final Exam

Text Book

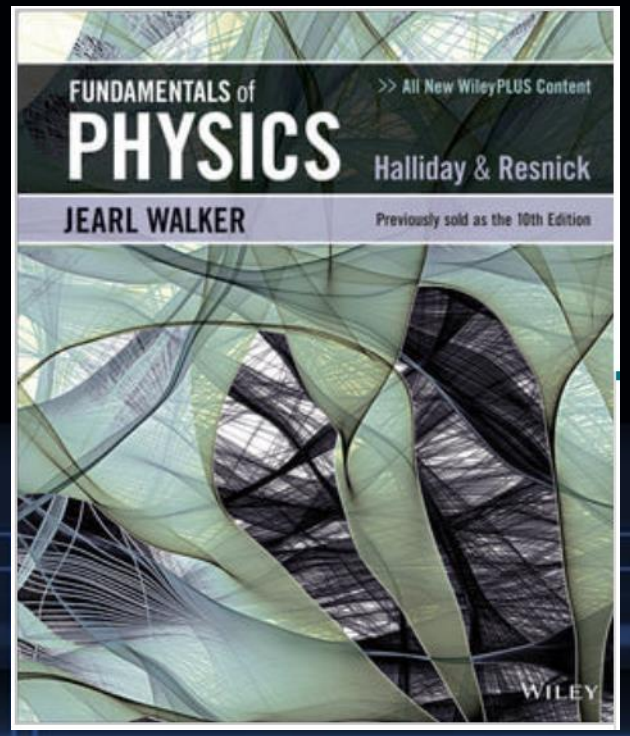
- Essential University Physics Volume 1, 4th Edition

Richard Wolfson



Reference Book

- Fundamentals of Physics, Extended, 11th Edition
  David Halliday, Robert Resnick, Jearl Walker



Learning Resources

- All the course material will be on eLearn platform. Slides will be provided before class started.
- Office Hours: 12:00~1:00 Monday @ Physics building R520 or by Microsoft Team(same link as online course) https://teams.live.com/meet/9570955571789

- TA

Chien-Chun Ding 丁建鈞(cyrusding0427@gmail.com)

Ching-Yeh Chen 陳慶燁(edward035358370@gapp.nthu.edu.tw)

Chiang-Yuan Hu胡將遠(a0935986668@gmail.com)

Evaluation

- Homework (25%)
- First midterm (25%)
- Second midterm (25%)
- Final (25%)

Homework

- 5 homework sets for the whole semesters. Each homework set due in a week.
- Homework sets will be posted on eLearn.
- Please hand in your homework via eLearn. No late homework will be accepted
- Discussion is encouraged. However, copying homework will results in 0 point for the whole homework set.

Exams

- There will be two midterms and one final. The dates are all set as shown in course calendar(10/25, 12/6, and 1/10).
- All three exams will be started at 8:00AM and ends at 9:50AM.
- You can bring one A4 information sheet for the exam.
- Cheating will result in 0 points for the whole exam and will be reported to university.

Exams Corrections for Midterm 1

- After you hand in your answer of the exam, you can work out a correction (open book) and hand in on eLearn within 48 hours.
- The correction must be work out by yourself. Copying others' answers will result in 0 points for the exam.
- A fully correct correction of an exam problem will earn 60% of the original scores.
- Taking the higher score of original or correction as the score of each single exam problem. Sum all the scores of the exam problem will be the final score of the exam.

Policy for COVID-19

- We follow university guideline about course under COVID-19.
- If on-site course is not allowed, we will have online course.
- For students who cannot attend exam due to COVID-19, they can have test remotely with monitor of web camera.
- If on-site exam is not allowed, we will have take-home exam instead.

Notes about the course

- Don’t hesitate to raise your hand if you have questions during the class.
- Any suggestions or comments on improving the pedagogy is more than welcome and is highly appreciated.
- If you have difficulty to catch up this course, please contact me. A midterm warning may be sent out for students who don’t perform well.