普通物理 A （科號：11120PHYS114402）

General Physics (II) — Spring, 2023

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- 教科書 (Textbook)

  建議 (不指定)：**Young & Freedman ~ University Physics with Modern Physics (E15, 2020)**

- 參考書籍 (References)
  1. **Giancoli** ~ **Physics for Scientists and Engineers with Modern Physics** (極推薦 2008 版本)
  2. Serway ~ a. Serway's Principles of Physics

     b. Physics for Scientists and Engineers with Modern Physics
  3. Walker, Halliday and Resnick ~ Fundamentals of Physics (Extended Version)
  4. Benson ~ University Physics

- 教學方式 (Teaching Method)

  課堂講課以簡報教材為主（搭配板書補充），說明物理概念的建立與聯結；
  經由微積分與解微分方程，熟悉物理模式的形成和理論的表現；
  注重學生出席率，講課進行中會點名同學提問與討論。

  如學生可落實課前預習教材和課後閱讀課文，
  必然有助於後續專業科目的學習拓展。

  警惕：教學進度快，修課學生每週至少須投入 6 小時課後時間複習和作業；非誠請莫入。

- 教學進度 (Syllabus)

  課程預定約三、四週介紹一主題。第一個主題是靜電學 (Electrostatics)，後三個主題依序為磁學與電磁感應 (Magnetostatics and Electromagnetic Induction)，光波 (Light and Optics) 與特殊相對論 (Special Relativity)，量子物理簡介 (Introduction to Quantum Physics)。

- 成績考核 (Evaluation)

  考試 75% (期中考兩次以及期末考、各佔 25%)，作業 25%；Extra Credits。
  考試未到者除病假（需醫師、藥單證明）或公假外，該次以零分計。
  積極參加晚間題解課的同學，可獲得助教的加分推薦，最高 5%。
  勉勵：題解課全勤者得參加期中考的補考；勤做筆記和作業的同學，學期成績從優加分。

- 題解課演習 (Course Tutoring)

  時段一：週二 18:30 – 20:00，助教講解範例以及解釋課堂內容疑難處；
  時段二：開學後依同學們的需要與協調另訂。

This course focuses on electromagnetic phenomena and quantum effects. We will review four Maxwell equations, closely related to the daily electromagnetic experiences, and introduce key concepts of quantum physics, mainly responsible for various applications of quantum mechanics. The central theme of this course emphasizes that the quantum age is coming and, in particular, with substantial effects on electric, magnetic, and/or optical properties of matter.

Maxwell's Equations[a]

Name	Equation
Gauss' law for electricity	$\oint \vec{E} \cdot d\vec{A} = q_{\text{enc}}/\varepsilon_0$
Gauss' law for magnetism	$\oint \vec{B} \cdot d\vec{A} = 0$
Faraday's law	$\oint \vec{E} \cdot d\vec{s} = -\dfrac{d\Phi_B}{dt}$
Ampere–Maxwell law	$\oint \vec{B} \cdot d\vec{s} = \mu_0\varepsilon_0 \dfrac{d\Phi_E}{dt} + \mu_0 i_{\text{enc}}$

[a]Written on the assumption that no dielectric or magnetic materials are present.

Integral form	Differential form
$\oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \dfrac{Q}{\epsilon_0}$	$\vec{\nabla} \cdot \vec{\mathbf{E}} = \dfrac{\rho}{\epsilon_0}$
$\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = 0$	$\vec{\nabla} \cdot \vec{\mathbf{B}} = 0$
$\oint \vec{\mathbf{E}} \cdot d\vec{\boldsymbol{\ell}} = -\dfrac{d\Phi_B}{dt}$	$\vec{\nabla} \times \vec{\mathbf{E}} = -\dfrac{\partial \vec{\mathbf{B}}}{\partial t}$
$\oint \vec{\mathbf{B}} \cdot d\vec{\boldsymbol{\ell}} = \mu_0 I + \mu_0 \epsilon_0 \dfrac{d\Phi_E}{dt}$	$\vec{\nabla} \times \vec{\mathbf{B}} = \mu_0 \vec{\mathbf{j}} + \mu_0 \epsilon_0 \dfrac{\partial \vec{\mathbf{E}}}{\partial t}$

†$\vec{\nabla}$ stands for the *del operator* $\vec{\nabla} = \hat{\mathbf{i}}\dfrac{\partial}{\partial x} + \hat{\mathbf{j}}\dfrac{\partial}{\partial y} + \hat{\mathbf{k}}\dfrac{\partial}{\partial z}$ in Cartesian coordinates.

One-dimensional Schrödinger Wave Equation: $\mathcal{H}_{\text{op}}\Psi(x,t) = i\hbar\frac{\partial}{\partial t}\Psi(x,t)$.

$$\mathcal{H}_{\text{op}} = \boldsymbol{T}_{\text{op}} + V(x) \quad \text{where} \quad \boldsymbol{T}_{\text{op}} = \frac{\hat{p}_x^{\,2}}{2m} = \frac{(\hbar/i)^2}{2m}\frac{\partial^2}{\partial x^2}$$

$$\Rightarrow \left[-\frac{\hbar^2}{2m}\frac{d^2}{dx^2} + V(x)\right]\psi(x) = E\psi(x) \quad \text{with} \quad \Psi(x,t) = \psi(x)e^{-iEt/\hbar}$$

In the 3-dimensional case, $V = V(\vec{\boldsymbol{r}}) = V(x,y,z)$:

$$\hat{p}_x \equiv \frac{\hbar}{i}\frac{\partial}{\partial x} \quad \Rightarrow \quad \hat{\vec{\boldsymbol{p}}} \equiv \frac{\hbar}{i}\vec{\nabla} = \frac{\hbar}{i}\left(\vec{\boldsymbol{e}}_x\frac{\partial}{\partial x} + \vec{\boldsymbol{e}}_y\frac{\partial}{\partial y} + \vec{\boldsymbol{e}}_z\frac{\partial}{\partial z}\right)$$

$$\Rightarrow \quad \boldsymbol{T}_{\text{op}} = -\frac{\hbar^2}{2m}\nabla^2 = -\frac{\hbar^2}{2m}\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right)$$

The Laplacian ∇^2 in the spherical coordinate system is expressed as

$$\nabla^2 = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right) + \frac{1}{r^2}\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right) + \frac{1}{\sin^2\theta}\frac{\partial^2}{\partial\phi^2}\right]$$

According to the Coulomb attraction between the electron and proton in a hydrogen atom, $V(r) = -ke^2/r$, we apply the time-independent Schrödinger equation in spherical coordinates to describe a single particle of reduced mass $\boldsymbol{\mu}$ $(1/\boldsymbol{\mu} = 1/M_p + 1/m_e)$ moving in a three-dimensional space:

(1) $\mathcal{H}_{\text{op}}\Psi(\vec{\boldsymbol{r}},t) = i\hbar\frac{\partial}{\partial t}\Psi(\vec{\boldsymbol{r}},t) = E\psi(r,\theta,\phi)e^{-iEt/\hbar}$ since $\Psi(\vec{\boldsymbol{r}},t) = \psi(r,\theta,\phi)e^{-iEt/\hbar}$

$$\Rightarrow \boxed{\mathcal{H}_{\text{op}}\psi(r,\theta,\phi) = \left[-\frac{\hbar^2}{2\mu}\nabla^2 + V(\vec{\boldsymbol{r}})\right]\psi(r,\theta,\phi) = E\psi(r,\theta,\phi)}$$

$$\because \quad V(\vec{\boldsymbol{r}}) = V(r) = -\frac{ke^2}{r}$$

$$\therefore \quad \mathcal{H}_{\text{op}} = -\frac{\hbar^2}{2\mu}\left\{\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right) + \frac{1}{r^2}\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right) + \frac{1}{\sin^2\theta}\frac{\partial^2}{\partial\phi^2}\right]\right\} - \frac{ke^2}{r}$$

(2) $$-\frac{\hbar^2}{2\mu}\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial\psi(r,\theta,\phi)}{\partial r}\right) + \left[-\frac{ke^2}{r} + \frac{\hat{L}^2}{2\mu r^2}\right]\psi(r,\theta,\phi) = E\psi(r,\theta,\phi)$$

(3) $$\begin{cases} -\frac{\hbar^2}{2\mu}\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial R_{nl}(r)}{\partial r}\right) + \left[-\frac{ke^2}{r} + \frac{l(l+1)\hbar^2}{2\mu r^2}\right]R_{nl}(r) = ER_{nl}(r) \\ \boxed{\hat{L}^2 Y_{lm}(r) = l(l+1)\hbar^2 Y_{lm}(\theta,\phi)} \quad \text{and} \quad \boxed{\hat{L}_z Y_{lm}(r) = m\hbar Y_{lm}(\theta,\phi)} \end{cases}$$