D.C. Kim

Biological Physics

supplementary note

October 27, 2022

Chung-Ang University

Contents

Acronyms

Use the template *acronym.tex* together with the document class SVMono (monograph-type books) or SVMult (edited books) to style your list(s) of abbreviations or symbols.

Lists of abbreviations, symbols and the like are easily formatted with the help of the Springer-enhanced `description` environment.

ABC   Spelled-out abbreviation and definition
BABI   Spelled-out abbreviation and definition
CABR   Spelled-out abbreviation and definition

Chapter 1
What the ancients knew

어떻게 organisms가 높은 ordered로 살 수 있는가? 에너지의 흐름이 order를 증가시킨다.

1.1 Heat

1.1.1 Heat is a form of energy

마찰은 mechanical energy를 thermal form으로 변환한다. Thermal energy가 적절히 구성되면 energy의 균형이 유지된다.

sunlight, potential energy of a rock은 높은 quality, thermal energy는 poor quality를 가진다. Quality of energy는 항상 어떤 과정을 거쳐 degrade된다.

1.1.2 Just a little history

마찰에 의해 생기는 열은 마찰에 반하는 역학적 일에 어떤 상수를 곱한 값과 같다.

$$\text{(heat produced)} = \text{(mechanical energy input)} \times (0.24\,\text{cal/J}) \tag{1.1}$$

System이 original state로 가는 process에 있다고 가정하자(cyclic process이다). system에 가해지는 전체 역학적 일은, 그리고 system에 의한 일은 전체 열과 같다.

1.1.3 Preview: The concept of free energy

자유 에너지는 다음과 같은 간단한 식으로 주어진다.

$$F = E - TS \tag{1.2}$$

System이 고정된 온도 T에 있을 때, 어떤 과정의 전체 효과가 system의 free energy F를 감소시킨다면 이 과정은 자발적으로 진행된다. 따라서 만약 system의 free energy가 이미 최소라면, 어떠한 자발적 변화도 일어나지 않을 것이다.

1.2 How life generates order

1.2.1 The puzzle of biological order

제2 법칙은 오직 *isolated* system에서만 적용된다.

Energy의 flow는 order를 증가시킬 수 있다.

1.2.2 A paradigm for free energy transduction

Osmotic flow 처음에는 sugar가 오른편에서 uncovered하지만, dissolve되고 spread 되어 오른 chamber로 가면, mysterious한 force가 피스톤을 오른쪽으로 밀기 시작한다. 이러한 과정은 **osmotic flow**라 한다.

system은 주위에서 *heat*를 흡수한다. 이러한 thermal energy는 mechanical work 로 변환된다. order가 paying되어 이러한 일이 일어날 수 있다. Osmotic flow는 *molecular order*을 희생하여 random thermal notion을 load에 반하는 mechanical motion으로 organize한다.

reverse osmosis(or "ultrafiltration")은 *system*에 *energy*를 흘려줌으로써 *mechanical form*을 *thermal form*으로 *degrade*하고 *order*를 증가시킨다.

Preview: Disorder as information Room temperature에서

$$(\text{maximum work}) \approx N \times (4.1 \times 10^{-21} \, \text{J} \times \gamma). \tag{1.3}$$

여기서 N은 dissolved sugar molecules의 개수이다. γ는 지금은 중요하지 않은 수치적 상수이다. 식 (1.3)은 entropy의 의미에 대해 말해준다.

$$T\Delta S \approx N \times (4.1 \times 10^{-21}\,\text{J} \times \gamma). \tag{1.4}$$

처음 sugar 분자는 전체 volume의 절반에 confined되어 있었다. 그리고 마지막에 그들은 confined되지 않았다. Pistons의 움직임과 같은 손실은 chamber의 절반 중 어디에 sugar molecule이 들어있냐는 것과 같은 정보이다.

$$\Delta S = \text{constant} \times (\text{number of bits lost}). \tag{1.5}$$

1.3 Excursion: Commercials, philosophy, pragmatics

1.4 How to do better on exams (and discover new physical laws)

1.5 Other key ideas from physics and chemistry

1.5.1 Molecules are small

1.5.2 Molecules are particular spatial arrangements of atoms

1.5.3 Molecules have definite internal energies

1.5.4 Low-density gases obey a universal law

$$k_{\text{B}}T_{\text{r}} \approx 4.1\,\text{pN}\cdot\text{nm}. \tag{1.6}$$

Chapter 2

What's inside cells

Biological question: 어떻게 cell들은 그들의 무수한 chemical processes와 reactants를 organize하는가?

Physical idea: (a) Bilayer membranes는 그들의 구성 분자들로부터 *self-assemble*한다; 세포는 이를 이용해 separate compartments로 스스로 partition한다. (b) Cells는 *active transport*를 이용해 synthesized materials를 특정한 destinations에 수송한다. (c) Biochemical processes는 매우 *specific*하다: 대부분은 enzymes에 의해 mediated되는데, 하나의 특정한 target molecule을 선택하고 나머지는 내버려둔다.

2.1 Cell physiology

Roadmap

Chapter 3

The molecular dance

3.1 The probabilistic facts of life

3.1.1 Discrete distributions

We say the **probability** of observing x_i is $P(x_i)$, where

$$N_i/N \rightarrow P(x_i) \text{ for large } N. \tag{3.1}$$

Since the probability of observing *some* value of x is 100% (that is, 1), we must have

$$\sum_i P(x_i) = (N_1 + N_2 + \cdots)/N = N/N = 1. \tag{3.2}$$

3.1.2 Continuous distributions

We say that the probability of observing x in this interval is $P(x_0)dx$, where

$$dN(x_0)/N \rightarrow P(x_0) \text{ for large } N. \tag{3.3}$$

$$\int_a^b dx \, P(x) = 1. \tag{3.4}$$

The Gaussian distribution is

$$P(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(x-x_0)^2/2\sigma^2}.$$ (3.5)

3.1.3 Mean and variance

The **average** (or **mean** or **expectation value**) of x for any distribution is written $\langle x \rangle$ and defined by

$$\langle x \rangle = \begin{cases} \sum_i x_i P(x_i) & \text{, discrete} \\ \int dx\, x P(x) & \text{, continuous.} \end{cases}$$ (3.6)

More generally, even if we know the distribution of x we may instead want the mean value of some other quantity $f(x)$ depending on x. We can find $\langle f \rangle$ via

$$\langle f \rangle = \begin{cases} \sum_i f(x_i) P(x_i) & \text{, discrete} \\ \int dx\, f(x) P(x) & \text{, continuous.} \end{cases}$$ (3.7)

If you go out and measure x just once you won't necessarily get $\langle x \rangle$ right on the nose. There is some spread, which we measure using the **root-mean-squre deviation** (or **RMS deviation**, or **standard deviation**):

$$\text{RMS deviation} = \sqrt{\langle (x - \langle x \rangle)^2 \rangle}.$$ (3.8)

3.1.4 Addition and multiplication rules

Addition rule The probability that the next measured value of x is either x_i or x_j equals $P(x_i) + P(x_j)$, unless $i = j$. For a continuous distribution, the probability that the next measured value of x is either between a and b or between c and d equals the sum, $\int_a^b dx\, P(x) + \int_c^d dx\, P(x)$, provided the two intervals don't overlap.

Multiplication rule Multiplication rule says

$$P_{\text{joint}}(x_i, y_K) = P_{\text{coin}}(x_i) \times P_{\text{die}}(y_K).$$ (3.9)

Chapter 4
Spin

4.1 Spin이 무엇인가?

고전적으로 비교할 만한 것이 없는 전자의 새로운 자유도이다. 전자는 $s = 1/2$인 intrinsic angular momentum을 갖는다.

4.2 Disjoint Set

경로 압축을 통한 `find` 연산의 최적화와 랭크에 의한 합치기를 통한 `union` 연산의 최적화로 상호 배타적으로 이루어진 집합을 합치거나 어떤 원소의 집합을 판별하는 작업을 거의 $\mathcal{O}(1)$에 해낼 수 있다.

4.3 Section Heading

Use the template *chapter.tex* together with the document class SVMono (monograph-type books) or SVMult (edited books) to style the various elements of your chapter content conformable to the Springer Nature layout.

4.4 Section Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the LATEX automatism for all your cross-references and citations.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

Use the standard `equation` environment to typeset your equations, e.g.

$$a \times b = c \ , \tag{4.1}$$

however, for multiline equations we recommend to use the `eqnarray` environment[1].

$$|\nabla U_\alpha^\mu(y)| \le \frac{1}{d-\alpha} \int \left| \nabla \frac{1}{|\xi - y|^{d-\alpha}} \right| d\mu(\xi) = \int \frac{1}{|\xi - y|^{d-\alpha+1}} d\mu(\xi) \tag{4.2}$$

$$= (d-\alpha+1) \int_{d(y)}^\infty \frac{\mu(B(y,r))}{r^{d-\alpha+2}} dr \le (d-\alpha+1) \int_{d(y)}^\infty \frac{r^{d-\alpha}}{r^{d-\alpha+2}} \tag{4.3}$$

4.4.1 Subsection Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Further on please use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. 4.4.

> Please do not use quotation marks when quoting texts! Simply use the `quotation` environment – it will automatically be rendered in the preferred layout.

4.4.1.1 Subsubsection Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. 4.4.1, see also Fig. 4.1[2]

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

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[1] In physics texts please activate the class option `vecphys` to depict your vectors in ***boldface-italic*** type - as is customary for a wide range of physical subjects.

[2] If you copy text passages, figures, or tables from other works, you must obtain *permission* from the copyright holder (usually the original publisher). Please enclose the signed permission with the
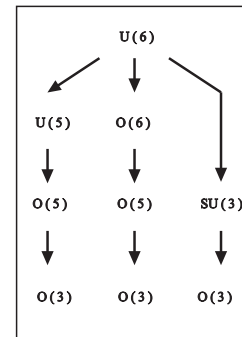
Paragraph Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. 4.4.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

For typesetting numbered lists we recommend to use the `enumerate` environment – it will automatically render Springer's preferred layout.
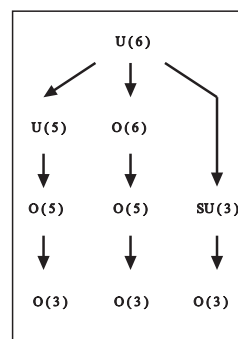
1. Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.

   a. Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.
   b. Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.

2. Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.

Fig. 4.1 If the width of the figure is less than 7.8 cm use the `sidecapion` command to flush the caption on the left side of the page. If the figure is positioned at the top of the page, align the sidecaption with the top of the figure – to achieve this you simply need to use the optional argument `[t]` with the `sidecaption` command

U(6)

U(5)　O(6)

O(5)　O(5)　SU(3)

O(3)　O(3)　O(3)

Fig. 4.2 Please write your
figure caption here

```
                    U(6)


          U(5)      O(6)


          O(5)      O(5)     SU(3)


          O(3)      O(3)     O(3)
```

Subparagraph Heading

In order to avoid simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. 4.4, see also Fig. 4.2.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

For unnumbered list we recommend to use the `itemize` environment – it will automatically render Springer's preferred layout.

- Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development, cf. Table 4.1.

  - Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.
  - Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.

- Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.

Run-in Heading Boldface Version Use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. 4.4.

Run-in Heading Boldface and Italic Version Use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. 4.4.

Table 4.1 Please write your table caption here

Classes	Subclass	Length	Action Mechanism
Translation	mRNA^a	22 (19–25)	Translation repression, mRNA cleavage
Translation	mRNA cleavage	21	mRNA cleavage
Translation	mRNA	21–22	mRNA cleavage
Translation	mRNA	24–26	Histone and DNA Modification

^{a} Table foot note (with superscript)

Run-in Heading Displayed Version

Use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. 4.4.

4.5 Section Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. 4.4.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

If you want to list definitions or the like we recommend to use the Springer-enhanced `description` environment – it will automatically render Springer's preferred layout.

Type 1   That addresses central themes pertainng to migration, health, and disease. In Sect. 4.3, Wilson discusses the role of human migration in infectious disease distributions and patterns.

Type 2   That addresses central themes pertainng to migration, health, and disease. In Sect. 4.4.1, Wilson discusses the role of human migration in infectious disease distributions and patterns.

4.5.1 Subsection Heading

In order to avoid simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Use the LaTeX automatism for all your cross-references and citations citations as has already been described in Sect. 4.4.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

If you want to emphasize complete paragraphs of texts we recommend to use the newly defined Springer class option `graybox` and the newly defined environment `svgraybox`. This will produce a 15 percent screened box 'behind' your text.

If you want to emphasize complete paragraphs of texts we recommend to use the newly defined Springer class option and environment `svgraybox`. This will produce a 15 percent screened box 'behind' your text.

4.5.1.1 Subsubsection Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. 4.4.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

Theorem 4.1 *Theorem text goes here.*

Definition 4.1 Definition text goes here.

Proof Proof text goes here.   □

Table 4.2 Table template 5

		A	B	C
A, C 스침	P 관성계	T	T	T
	Q 관성계	T	$T + \frac{2Lv}{c\sqrt{c^2-v^2}}$	T
B, C 스침	P 관성계	$T + \frac{2L}{v}$	$T + \frac{2L}{v}$	$T + \frac{2L\sqrt{c^2-v^2}}{cv}$
	Q 관성계	$T + \frac{2L}{v} - \frac{2Lv}{c\sqrt{c^2-v^2}}$	$T + \frac{2L}{v}$	$T + \frac{2L\sqrt{c^2-v^2}}{cv}$

Paragraph Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. 4.4.

Note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

Theorem 4.2 *Theorem text goes here.*

Definition 4.2 Definition text goes here.

Proof Proof text goes here.   □

Trailer Head

If you want to emphasize complete paragraphs of texts in an `Trailer Head` we recommend to use

```
\begin{trailer}{Trailer Head}
...
\end{trailer}
```

? Questions

If you want to emphasize complete paragraphs of texts in an `Questions` we recommend to use

```
\begin{question}{Questions}
...
\end{question}
```

> **Important**

If you want to emphasize complete paragraphs of texts in an `Important` we recommend to use

```
\begin{important}{Important}
...
\end{important}
```

! Attention

If you want to emphasize complete paragraphs of texts in an `Attention` we recommend to use

```
\begin{warning}{Attention}
...
\end{warning}
```

Program Code

If you want to emphasize complete paragraphs of texts in an `Program Code` we recommend to use

```
\begin{programcode}{Program Code}
\begin{verbatim}...\end{verbatim}
\end{programcode}
```

Tips

If you want to emphasize complete paragraphs of texts in an `Tips` we recommend to use

```
\begin{tips}{Tips}
...
\end{tips}
```

Overview

If you want to emphasize complete paragraphs of texts in an `Overview` we recommend to use

```
\begin{overview}{Overview}
```

```
...
\end{overview}
```

Background Information

  If you want to emphasize complete paragraphs of texts in an `Background Information` we recommend to use

    `\begin{backgroundinformation}{Background Information}`

    `...`

    `\end{backgroundinformation}`

Legal Text

  If you want to emphasize complete paragraphs of texts in an `Legal Text` we recommend to use

    `\begin{legaltext}{Legal Text}`

    `...`

    `\end{legaltext}`

Appendix

When placed at the end of a chapter or contribution (as opposed to at the end of the book), the numbering of tables, figures, and equations in the appendix section continues on from that in the main text. Hence please *do not* use the `appendix` command when writing an appendix at the end of your chapter or contribution. If there is only one the appendix is designated "Appendix", or "Appendix 1", or "Appendix 2", etc. if there is more than one.

$$a \times b = c \tag{4.4}$$

Problems

3.20 A given problem or Excercise is described here. The problem is described here. The problem is described here.
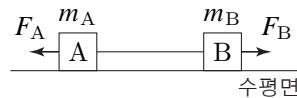
3.21 Problem Heading

(a) The first part of the problem is described here.

(b) The second part of the problem is described here.

3.22 Generalized tension

일반적으로 실의 장력을 구하기 위해 가속도를 구하고 이를 이용하여 한 물체에 대한 힘을 분석하지만, 때때로 가속도가 포함되지 않은 식을 이용하는 것이 유용하다.

(a) 그림과 같이 마찰이 없는 수평면에 질량이 각각 m_A, m_B인 물체 A, B가 놓여 있고, 각각 반대 방향으로 힘 F_A, F_B가 작용한다. 편의상 물체의 가속도의 방향이 F_B와 같다고 하고, 가속도 a를 m_A, m_B, F_A, F_B에 대한 식으로 나타내라.

$$F_A \quad m_A \qquad m_B \quad F_B$$
$$\longleftarrow \boxed{A} \text{——————} \boxed{B} \longrightarrow$$
$$\text{수평면}$$

(b) 이번에는 A에 작용하는 힘만을 고려하여 실의 장력 T를 m_A, F_A, a에 대한 식으로 나타내라.

(c) 앞선 두 결과를 이용하여 a를 소거하여 실의 장력에 대한 식을 얻어라. 그리고 이 식을 기하학적 의미를 해석하라.

(d) *(23학년도 9월 14번)* (가)와 (나)에서 실 q에 걸린 장력을 m, M, g, 빗면 가속도 a에 대해 나타내고 두 값이 동일함을 확인하라. (가)에서 실 q에 걸린 장력이 $4mg$임은 명백히 알 수 있다. (가)에서 p가 B를 당기는 힘의 조건이 필요 없음을 확인하라.

(e) *(22학년도 10월 13번)* 물체 A, B에 대해 각각 실에 걸린 장력을 물체와 추의 질량, 중력 가속도 g, 빗면 가속도 a에 대해 나타내라. 걸린 시간이 4초, 2초인 조건이 필요 없음을 확인하라.

Appendix A
Chapter Heading

All's well that ends well

Use the template *appendix.tex* together with the Springer document class SVMono (monograph-type books) or SVMult (edited books) to style appendix of your book.

A.1 Section Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the LaTeX automatism for all your cross-references and citations.
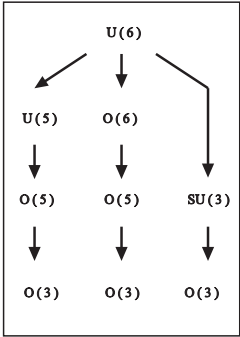
A.1.1 Subsection Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Furtheron please use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. A.1.

For multiline equations we recommend to use the `eqnarray` environment.

$$\mathbf{a} \times \mathbf{b} = \mathbf{c}$$
$$\mathbf{a} \times \mathbf{b} = \mathbf{c} \tag{A.1}$$

Fig. A.1 Please write your
figure caption here

A.1.1.1 Subsubsection Heading

Instead of simply listing headings of different levels we recommend to let every
heading be followed by at least a short passage of text. Furtheron please use the
LaTeX automatism for all your cross-references and citations as has already been
described in Sect. A.1.1.

Please note that the first line of text that follows a heading is not indented, whereas
the first lines of all subsequent paragraphs are.

Table A.1 Please write your table caption here

Classes	Subclass	Length	Action Mechanism
Translation	mRNA^a	22 (19–25)	Translation repression, mRNA cleavage
Translation	mRNA cleavage	21	mRNA cleavage
Translation	mRNA	21–22	mRNA cleavage
Translation	mRNA	24–26	Histone and DNA Modification

^{a} Table foot note (with superscript)

Glossary

Use the template *glossary.tex* together with the Springer document class SVMono (monograph-type books) or SVMult (edited books) to style your glossary in the Springer layout.

glossary term Write here the description of the glossary term. Write here the description of the glossary term. Write here the description of the glossary term.

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Solutions

Problems of Chapter ??

3.20 The solution is revealed here.

3.21 Problem Heading

(a) The solution of first part is revealed here.

(b) The solution of second part is revealed here.