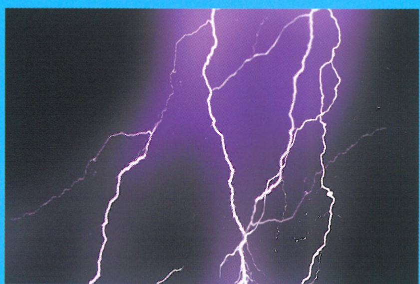
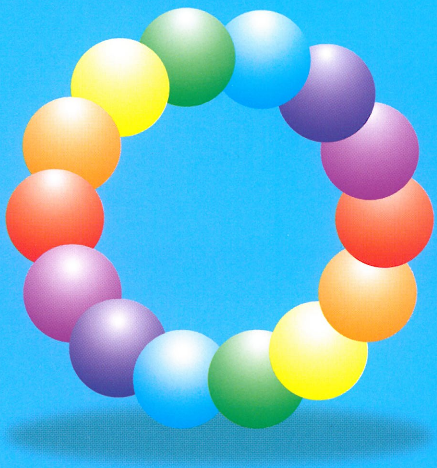
Through the Wonders of Physics



物理から∞

With extracts from
Walter Lewin's
For the Love of Physics

Tomoko Hanasaki



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EIHŌSHA

Through the Wonders of Physics

With extracts from
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はじめに

中上位の英語学習者を対象とする本書は次の2点を狙いとしている。

1　迅速かつ正確に必要な情報を「読み取る」技術の習得

2　そのために必要な語彙表現の拡充

様々な読み方の基本についてはまず、巻頭の Reading Strategies を参照されたい。各単元には、読む際の関心、問題意識を喚起する問題 (Before You Read)や解答しながら再読し、時には言説の意味あいを正確に捉え直すための問題 (After You Read) を収め、さらには本文のことばの特徴についての評論も書きおろした。問題は単元が進むにつれ、難しくなっている。読む題材として本文に挙がっているものは MIT名誉教授の人気書、 *For the Love of Physics* に拠る。これは学生に話しかける口調で、極めて平易な米英語で書かれた文章で、速読力と相関的に聴解力を高めるためにも使用されたい。専門講義を英語で聞き取る練習に役立ちそうな問題も、適宜、 Before You Read あるいは After You Read に収めている。

本書を使用して、教養ある読者を対象にした科学書は英語で読むとおもしろい、物理はこんなに面白かったと思ったなら、そして、そこから先に繋がる何かを得てくれたら (*Through the Wonders of Physics*) 幸いである。

T. H.

2013年9月

Contents

Reading Strategies

Prediction

Before you read, you look at the title, pictures and charts (if there are any), and predict the content. Having some idea of the subject matter will help you concentrate more on the reading.

Skimming

You run through the text to get the main ideas or facts in it. Skimming is useful when you have a lot of reading materials to go through and / or when you need to choose one out of many items for close reading.

Scanning

You move your eyes quickly over the text to find particular information. You will need to scan through a text when you want to find a particular fact or idea in it.

Close reading

You read closely; that is, you read every single word, weighing its meaning.

Unit 1

Before You Read

A Look at the title. Skim the text very quickly. What other questions can you find?

....

....

B Do you know the answers to the questions? Discuss with a partner.

....

Why is the sky blue?

Just look up in the sky and ask yourself some obvious questions: Why is the sky blue, why are sunsets red, why are clouds white? Physics has the answers! The light of the Sun is composed of all the colors of the rainbow. But as it makes its way through the atmosphere it scatters in all directions off air molecules and very tiny dust particles (much smaller than a micron, which is 1/250,000 of an inch). This is called Rayleigh scattering. Blue light scatters the most of all colors, about five times more than red light. Thus when you look at the sky during the day in any direction*, blue dominates, which is why the sky is blue. If you look at the sky from the surface of the Moon (you may have seen pictures), the sky is not blue—it's black, like our sky at night. Why? Because the Moon has no atmosphere.

Why are sunsets red? For exactly the same reason that the sky is blue. When the Sun is at the horizon, its rays have to travel through more atmosphere, and the green, blue, and violet light get scattered the most—filtered out of the light, basically. By the time the light reaches our eyes—and the clouds above us—it's made up largely of yellow, orange, and especially red. That's why the sky sometimes almost appears to be on fire at sunset and sunrise.

Why are clouds white? The water drops in clouds are much larger than the tiny particles that make our sky blue, and when light scatters off these much larger

* Be careful — never look at the sun.

particles, all the colors in it scatter equally. This causes the light to stay white. But if a cloud is very thick with moisture, or if it is in the shadow of another cloud, then not much light will get through, and the cloud will turn dark.

One of the demonstrations I love to do is to create a patch of "blue sky" in my classes. I turn all the lights off and aim a very bright spotlight of white light at the ceiling of the classroom near my blackboard. The spotlight is carefully shielded. Then I light a few cigarettes and hold them in the light beam. The smoke particles are small enough to produce Rayleigh scattering, and because blue light scatters the most, the students see blue smoke. I then carry this demonstration one step further. I inhale the smoke and keep it in my lungs for a minute or so—this is not always easy, but science occasionally requires sacrifices. I then let go and exhale the smoke into the light beam. The students now see white smoke—I have created a white cloud! The tiny smoke particles have grown in my lungs, as there is a lot of water vapor there. So now all the colors scatter equally, and the scattered light is white. The color change from blue light to white light is truly amazing!

After You Read

A Comprehension

Complete the sentences. Check (✓) the correct option.

1 Rayleigh scattering occurs when sunlight traveling through air
   a) hits very tiny particles and disperses in all directions.
   b) goes through air molecules without bending.

2 Blue light scatters
   a) more than red light.
   b) less than yellow light.

3 Air molecules and tiny dust particles in the atmosphere
   a) make the sky blue during daytime.
   b) make the sky black when it is seen from space.

4 At sunset or sunrise, sunlight has to travel through more atmosphere, and
   a) blue light is basically lost to scattering.
   b) red light goes in all directions.

5 The water drops in clouds are
   a) much larger than air molecules.
   b) smaller than the smoke particles in a smoker's lungs.

6 The water drops in clouds
   a) scatter all colors of light equally.
   b) only scatter blue light.

B Vocabulary

Complete the sentences. Use the words in the box.

atmosphere	composed	exhale	inhale	moisture	molecules	scatters

1 The light of the Sun is .... of all the colors of the rainbow.

2 Light scatters off air .... and tiny dust particles.

3 Blue light .... about five times more than red light.

4 The Moon has no ....

5 If a cloud is very thick with ...., then not much light will get through.

6 I .... the smoke and keep it in my lungs for a minute or so, then let go and .... the smoke into the light beam.

C Analysis

Complete the sentences.

In class, Professor Lewin uses a very bright spotlight of white light as ___ ___, smoke particles as ___ _________ and ____ _________, and the smoke particles that have grown moist in his lungs as ___ _____ _____ in clouds. He uses them to show how we come to see a patch of ____ ___ and _____ ______.

D Listening

Listen and answer the questions.

1 With this demonstration, what questions does he say he is able to answer?

....

2 What other related questions or topics does he think yet remain unanswered?

....

Unit 2

Before You Read

A Do you think you are shorter standing up than lying down? Discuss with a partner.

....

B Skim the text very quickly. In a nutshell, what is the answer to the question?

....

Are you shorter standing up?

There simply is no physics without measurements. And just as important, there are no meaningful measurements without uncertainties.

You count on reasonable amounts of uncertainty all the time, without realizing it. When your bank reports how much money you have in your account, you expect an uncertainty of less than half a penny. When you buy a piece of clothing online, you expect its fit not to vary more than a very small fraction of a size. A pair of size 34 pants that varies just 3 percent changes a full inch in waist size; it could end up a 35 and hang on your hips, or a 33 and make you wonder how you gained all that weight.

My appreciation of the crucial role of measurements in physics is one reason I'm skeptical of theories that can't be verified by means of measurements. Take string theory, or its souped-up cousin superstring theory, the latest effort of theoreticians to come up with a "theory of everything". Theoretical physicists, and there are some brilliant ones doing string theory, have yet to come up with a single experiment, a single prediction that could test any of string theory's propositions. Nothing in string theory can be experimentally verified—at least so far.

When theory gets way out there, I am reminded of my grandmother, my mother's mother, a very great lady who had some wonderful sayings and habits that showed her to be quite an intuitive scientist. She used to tell me, for instance, that you are shorter when standing up than when lying down. I love to teach my students about this. On the first day of class I announce to them that in honor of my grandmother, I'm going to bring this outlandish notion to a test. They, of course, are completely bewildered. I can almost see them thinking, "Shorter standing up than lying down? Impossible!"

Their disbelief is understandable. Certainly if there is any difference in length between lying down and standing up it must be quite small. After all, if it was one foot, you'd know it, wouldn't you? You'd get out of bed in the morning, you'd stand up and go *clunk*—you're one foot shorter. But if the difference was only 0.1 centimeters ($^1/_{25}$ of an inch) you might never know. That's why I suspect that if my grandmother was right, then the difference is probably only a few centimeters, maybe as much as an inch.

To conduct my experiment, I of course first need to convince them of the uncertainty in my measurements. So I begin by measuring an aluminum rod vertically—it comes to 150.0 centimeters—and I ask them to agree that I'm probably capable of measuring it with an uncertainty of plus or minus one-tenth of a centimeter. So that vertical measurement is 150.0±0.1 centimeters. I then measure the bar when it's horizontal and come up with 149.9±0.1 centimeters, which is in agreement—within the uncertainty of the measurements—with the vertical measurement.

What did I gain by measuring the aluminum rod in both positions? A lot! For one, the two measurements demonstrate that I was able to measure length to an accuracy of about 0.1 centimeter (1 millimeter). But at least as important for me is the fact that I want to prove to the students that I'm not playing games with them. Suppose, for example, that I have prepared a specially "cooked" meter stick for my horizontal measurements—that would be a terrible, very dishonest thing to do. By showing that the length of the aluminum rod is the same in the two measurements, I establish that my scientific integrity is beyond doubt.

I then ask for a volunteer, measure him standing up, write that number on the blackboard—185.2 centimeters (or just over 6 feet), plus or minus 0.1 centimeter of course, to account for the uncertainty. Then I help him lie down on my desk in my measuring equipment, which looks like a giant Ritz Stick, the wooden shoe-store foot-measuring device, only his whole body is the foot. I joke back and forth with him about how comfortable he is and congratulate him on his sacrifice for the sake of science, which makes him just a wee bit uneasy. What have I got up my sleeve?

I slide the triangular wooden block snug up against his head, and while he lies there, I write the new number on the board. So we now have two measurements, each uncertain by about 0.1 centimeters. What's the result?

Are you surprised to learn that the two measurements differ by 2.5 centimeters, plus or minus 0.2 centimeters of course? I have to conclude that he is in fact at least 2.3 centimeters (or about 0.9 inches) taller while lying down. I go back to my prone student, announce that he's roughly an inch taller sleeping than standing up, and—this is the best part—declare, "My grandmother was right! She was always right!"

Are you skeptical? Well, it turns out that my grandmother was a better scientist than most of us. When we are standing, the tug of gravity compresses the soft tissue between the vertebrae of our spines, and when we lie down, our spines expand. This may seem obvious once you know it, but would you have predicted it? In fact, not even the scientists at NASA anticipated this effect in planning the first space missions. The astronauts complained that their suits got tighter when they were in space. Studies done later, during the Skylab mission, showed that of the six astronauts who were measured, all six showed about 3 percent growth in height—a little over 2 inches if you're 6 feet tall. Now astronauts' suits are made with extra room to allow for this growth.

See how revealing good measurements can be?

After You Read

A Comprehension

Check (✓) the information that is correct.

1 Measurements and their uncertainties are at the heart of physics.

2 In everyday life we encounter inaccurate measurements all the time.

3 The author thinks that theoretical physicists should conduct experiments to verify their wonderful theories.

4 His grandmother was a scientist.

5 She used to say that you are shorter when standing up than when lying down.

6 In order to put this notion to test, the author carries out an experiment in class.

7 He first demonstrates that he is capable of measuring with an uncertainty of plus or minus $^1/_{10}$ of a centimeter.

8 He measures a student standing up, and then measures an aluminum rod vertically.

9 The experiment showed that the man was about an inch taller when lying down.

10 The scientists at NASA didn't know that you are about 3 percent shorter on earth than in space.

Why are we shorter standing up than when lying down?

....

....

B Vocabulary

Complete the sentences. Use the words in the box.

accuracy	anticipated	bewildered	count on	crucial
fraction	integrity	intuitive	predict	up my sleeve

1 You .... reasonable amounts of uncertainty all the time.

2 You expect uncertainty to be within a very small .... of a size.

3 Measurements play a .... role in physics.

4 She seemed to have an .... awareness of how gravity affects us.

5 Students are .... to hear that they are shorter standing up.

6 We are generally capable of measuring length to an .... of about 1 millimeter.

7 I establish that my scientific .... is beyond doubt.

8 What have I got ....?

9 Did you .... that the tug of gravity compresses the tissue between the vertebrae of our spines when we are standing?

10 No scientists at NASA .... this effect in planning the first space missions.

C Analysis

Which of these sentences state facts? Which are opinions?

1 Physics is fundamentally an experimental science.

2 Measurements and their uncertainties are at the heart of every experiment.

3 Theoretical physicists have yet to come up with a single experiment to test their propositions.

4 She used to tell me that you are shorter when standing up than when lying down.

5 Certainly if there is any difference in length between lying down and standing up, it must be quite small.

6 I measure an aluminum bar when it is horizontal and come up with 149.9±0.1 centimeters.

7 I congratulate him on his sacrifice for the sake of science.

8 My grandmother was right when she said, 'you are shorter when standing up than when lying down.'

9 My grandmother was a better scientist than most of us.

10 Now astronauts' suits are made with extra room to allow for 3% growth in height in space.

Learning tips

How to tell facts from opinions

FACTS are what actually happened.
OPINIONS are what someone believes to be right.
They have not been proven or verified.
They may be in the form of advice or judgment.
They are essentially personal, and there may be opposing views.

Language markers for opinions:
1) modal auxiliaries such as *may, might, could, must, should*
2) cognitive verbs such as *believe, claim, think, suppose*

If you don't see any of those, find clues in the context!

D Listening

Listen to a mini-lecture and complete the sentences.

1 ___________ and their ____________ are at the heart of every discovery.

2 Physicists express relationships through ___________ _________ about _________ _________ such as density, weight, and length.

Notes

Unit 2

string theory A theory of everything; it posits that the fundamental building blocks of matter are super-tiny vibrating strings, which produce all the so-called elementary particles by vibrating at different harmonic frequencies, and in many dimensions

Skylab The United States' first space station; it was launched and operated by NASA; three manned missions were made to the Skylab between 1973 and 1974

Unit 4

1 atmosphere 1.03 kilograms per square centimeter of pressure is called the standard atmosphere. Pressure is force divided by area: $P=F/A$. So, air pressure at sea level is about 1 kilogram per square centimeter

Unit 5

Baltimore Harbor Tunnel 2.33 km long; a pair of two-lane road tunnels under the Patapsco River in Baltimore, Maryland; it opened on November 29, 1957

the horrible accident in New York City in 2007 The steam pipe explosion near Grand Central Terminal in Manhattan on July 18 killed 1 and injured at least 18

Unit 6

Daniel Bernoulli A Swiss mathematician and physicist (1700-1782); one of the many prominent mathematicians in the Bernoulli family; he is remembered for his work in fluid mechanics and also for his pioneering work in probability and statistics

Unit 8

puncture that balloon cf burst somebody's bubble

play a piano we don't know what kind of piano can be played on the moon

Bruno Rossi (1905-1993) Professor Bruno Rossi at MIT was a leading Italian astrophysicist; he pioneered X-ray astronomy in the 1960s

Unit 9

fundamental The fundamental frequency is the lowest resonance frequency of a particular object; it is sometimes called the first harmonic

a suspension bridge a bridge that has no supports under it and is hung from strong steel ropes fixed to towers

Tacoma Narrows Bridge a 1.6 km-long twin suspension bridge that crosses the Tacoma Narrows in Washington and one of the largest suspended bridges built at the time; it was opened in July 1940; after its collapse in November 1940, it was rebuilt and reopened in 1950

amplitude the amplitude of a sound wave determines how loud or soft the sound will be; it is measured by the intensity of sound, which is expressed in decibels

the Millennium Bridge 370 meters long; a steel suspension bridge for pedestrians crossing the River Thames in London; it was opened in June 2000; Londoners nicknamed it the "Wobbly Bridge" because they experienced uncomfortable swaying motion on the bridge for the first two days of the opening; it reopened in 2002

damper a piece of equipment that stops a movement from being too strong

35,000-year-old flute the oldest known musical instrument discovered in a cave in Germany in June 2009; it is carved out of a vulture's wing bone, measuring 20cm long, and has five precisely

Glossary

複数形でも使用される用語は、斜体字の項目直後に () 内で語尾のみ、もしくは単語を記す。複数の訳語が顕著な場合は他の訳語を () 内で「または…」と記す。

A

acceleration 加速度
action 作用
air pressure 気圧
alternating (electric) current 交流（電流）
ammeter(s) 電流計
the amperage 電流量
amplitude(s) 振幅
the anvil (=incus) 砧骨（きぬたこつ）
the atmosphere 大気
atmospheric physics 大気物理学
atmospheric pressure 大気圧
atomic force microscope(s) 原子間力顕微鏡
atom(s) 原子

B

body (-dies) 物体

C

calculus 微積分
charged particle(s) 荷電粒子
commutator(s) 整流器
concert A (=the A above middle C on the piano) 中央ド音より右のラ音
conductor(s) 導体
the conservation of charge 電荷保存
constant(s) 定数
construction engineering 建設工学

D

defibrillators 除細動器
degaussing device(s) 消磁気装置
density 密度
diamagnetic material(s) 反磁性体
direct current 直流（電流）
discharge 放電

E

eardrum(s) 鼓膜
the Earth's magnetic field 地球の磁場（地磁気）
eddy current(s) 渦電流（うずでんりゅう）
electric breakdown 絶縁破壊
electric charge(s) 電荷（量）
electric current 電流
electric field(s) 電場（または電界）
the electric force 電気力
the electric potential difference 電位差（または電圧）
electrical stimulation (or *stim* for short) 電気刺激
electrode(s) 電極
electrodynamic suspension 電磁誘導支持方式（または磁気反発式浮上）
electromagnetic suspension 電磁吸引制御方式（または磁気吸引式浮上）
electromagnet(s) 電磁石
electromagnetic wave(s) 電磁波
electromagnetism 電磁気（学）
electron(s) 電子
equation(s) 公式（または方程式）

F

ferromagnetic material(s) 強磁性体
fluid(s) 流体
force(s) 力
frequency (-cies) 振動数
friction 摩擦