CHAPTER 2

TIMSS Advanced 2015 Physics Framework

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Similar to the TIMSS Advanced—Mathematics Framework, the assessment framework for TIMSS Advanced—Physics is organized around two dimensions: a content dimension specifying the domains or subject matter to be assessed within physics (i.e., mechanics and thermodynamics, electricity and magnetism, and wave phenomena and atomic/nuclear physics), and a cognitive dimension specifying the domains or thinking processes to be assessed (i.e., knowing, applying, and reasoning). The cognitive domains describe the thinking processes expected of students as they engage with the physics content.

In general, this framework is similar to that used in TIMSS Advanced 2008. However, there have been updates to particular topics to better reflect the content coverage of current high school physics curricula, standards, and frameworks of participating TIMSS Advanced countries. Consideration also was given to current research and initiatives in science and science education, such as the *Framework for K–12 Science Education* (National Research Council, 2012) developed in the United States, the *Physics Higher 2 Syllabus* (Singapore Examinations and Assessment Board, 2013) used in Singapore, the *Physics Curriculum (Secondary 4–6)* (Education Bureau, Hong Kong, SAR, 2007) used in Hong Kong and the *AP Physics Course Description* (College Board, 2012).

Exhibit 2 shows the target percentages of testing time devoted to each content and cognitive domain for the physics assessment.

Exhibit 2: Target Percentages of the TIMSS Advanced 2015 Physics Assessment Devoted to Content and Cognitive Domains

Content Domains	Percentages
Mechanics and Thermodynamics	40%
Electricity and Magnetism	25%
Wave Phenomena and Atomic/Nuclear Physics	35%

Cognitive Domains	Percentages
Knowing	30%
Applying	40%
Reasoning	30%

TIMSS Advanced—Physics Content Domains

e TIMSS Advanced—Physics Framework includes three content domains: mechanics and thermodynamics, electricity and magnetism, and wave phenomena and atomic/nuclear physics. e content covered in these three domains is very similar to the content coverage in the TIMSS Advanced 2008 Framework, except that the content was organized into four domains in 2008. Organizing the content in three domains will support the reporting of reliable student scores at the physics domain level for TIMSS Advanced 2015. is organization also follows the structure of many current high school physics curricula. In the TIMSS Advanced 2015 Framework, topics that were included in the heat and temperature domain in 2008 are now included in the mechanics and thermodynamics domain, and some topics regarding sound and light, which were included in the mechanics domain and the electricity and magnetism domains, respectively, in 2008, are now included in the domain that includes wave phenomena.

Each of the three content domains in the TIMSS Advanced—Physics Framework is divided into topic areas, and each topic in turn includes several topics. Across the TIMSS Advanced—Physics assessment, each topic receives approximately equal weight in terms of time allocated to assessing the topic.

r Forces and motion;

r e laws of conservation; and

r Heat and temperature.

Kinematics, dynamics (Newton's three laws of motion), and the law of gravitation are important components of this area. e conservation of certain physical quantities, such as energy or momentum, is a fundamental concept in physics that is expressed by the laws of conservation (energy and momentum) and the rst law of thermodynamics. e area of thermodynamics includes mechanisms of heat transfer and how properties of matter change with temperature.

Mechanics and Thermodynamics: Forces and Motion

1. Predict and determine the position, displacement, and velocity of bodies given initial conditions; and use Newton's laws of motion to explain the dynamics of di erent types of motion and to calculate displacement, velocity, acceleration, distance traveled, or time elapsed.
2. Identify forces, including frictional force, acting on a body at rest, moving with constant velocity, or moving with constant acceleration and explain how their combined action in uences the body's motion; and nd solutions to problems involving forces.
3. Determine the forces acting on a body moving in a circular path at constant velocity, the body's centripetal acceleration, its velocity, and the time for it to complete a full revolution.
4. Use the law of gravitation to determine the motion of celestial objects and the forces acting on them.

Mechanics and Thermodynamics: The Laws of Conservation

1. Apply the law of conservation of mechanical energy in practical contexts, including nding solutions to problems involving the transformation of potential to kinetic energy and vice versa.
2. Apply the law of conservation of linear momentum in elastic and inelastic collisions.
3. Solve problems using the rst law of thermodynamics.

Mechanics and Thermodynamics: Heat and Temperature

1. Demonstrate understanding of mechanisms of heat transfer and the mechanical equivalent of heat (work); and use speci c heats or heat capacities to predict equilibrium temperature when bodies of di erent temperature are brought together.
2. Determine the expansion of solids in relation to temperature change; and use the ideal gas law (in the form pV/T = constant) to solve problems and demonstrate an understanding of the limitations of this law.

Electricity and Magnetism

Electricity and magnetism are core areas of study in physics that have a wide range of practical applications. The TIMSS Advanced 2015 electricity and magnetism domain focuses on the following:

- Electricity and electric circuits; and
- Magnetism and electromagnetic induction.

Important concepts in electricity encompass the behavior of electrostatic charges and their motion in electric circuits, including the role of resistance and energy losses. Understanding the relationship between electricity and magnetism, including the interaction of charged particles with magnetic elds, the production of magnetic elds from current-carrying wires, and induction is central to this domain.

Electricity and Magnetism: Electricity and Electric Circuits

1. Calculate the magnitude and direction of the electrostatic attraction or repulsion between isolated charged particles by application of Coulomb's law.
2.

2. Demonstrate understanding of the relationship between magnetism and electricity in phenomena such as magnetic elds around electric conductors (Ampere's law), electromagnets, and electromagnetic induction.

3. Solve problems using Faraday's and Lenz' laws of induction.

Wave Phenomena and Atomic/Nuclear Physics

Wave phenomena and atomic/nuclear physics covers much of what is sometimes known as modern physics. is TIMSS Advanced 2015 domain focuses on two topic areas common to most participating countries' curricula:

- Wave phenomena; and
- Atomic and nuclear physics.

 e study of wave phenomena provides a bridge between classical and modern phsiets, anf iucudeimacnsi31.4(c)-2.6(a)(b)4(f wa)18.3(v)8.4(e p)7.4(h)4.3(e)1.3(n)4.3(o)12.4

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2. Demonstrate understanding of wave-particle duality, including applying knowledge of the photoelectric e ect to predict the consequence of changing the incoming intensity or wavelength of light and solving problems involving the wave nature of matter.
3. Demonstrate understanding of nuclear reactions and solve problems involving radioactive decay, such as nding the half-life of a radioactive isotope; and describe the role of nuclear reactions in nature (such as in stars), and explain their practical applications, such as in nuclear reactors.
4. Demonstrate understanding of mass-energy equivalence in nuclear reactions and particle transformations.

TIMSS Advanced—Physics Cognitive Domains

 e physics cognitive dimension is divided into three domains based on the thinking processes students are expected to use when encountering the physics items developed for the TIMSS Advanced 2015 assessment. e rst domain, knowing, addresses the students' ability to recall, recognize, and describe facts, concepts, and procedures that are necessary for a solid foundation in physics. e second domain, applying, focuses on using this knowledge to generate explanations and solve problems. e third domain, reasoning, includes using evidence and physics understanding to analyze, synthesize, and generalize, o en in unfamiliar situations and complex contexts. While there is some hierarchy across the three domains (from knowing to applying to and reasoning), each domain contains items representing a full range of di culty.

Each content domain includes items developed to address each of the three cognitive domains. Accordingly, the mechanics and thermodynamics domain includes knowing, applying, and reasoning items, as do the other content domains. e following sections further describe the thinking processes de ning the cognitive domains. e general descriptions are followed by lists of speci c behaviors to be elicited by items that are aligned with each domain.

Knowing

Items in this domain assess students' knowledge of facts, relationships, processes, concepts, and equipment. Accurate and broad-based factual knowledge enables students to successfully engage in the more complex cognitive activities essential to the scienti c enterprise.

Recall/Recognize	Identify or state facts, relationships, processes, phenomena,

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Analyze	Identify the elements of a scientific problem and use relevant information, concepts, relationships, and data patterns to answer questions or solve the problem.
Synthesize	Solve problems that require consideration of a number of different factors or related concepts; and integrate mathematical concepts in the solutions to physics problems.
Design Investigations	Plan investigations or procedures appropriate for answering scientific questions or testing hypotheses; and describe or recognize the characteristics of well-designed investigations in terms of variables to be measured and controlled as well as cause-and-effect relationships.
Formulate Questions/ Hypothesize/Predict	Formulate questions that can be answered by investigation and formulate testable assumptions based on theory, analysis of scientific information, and/or knowledge from observations; and use evidence and conceptual understanding to make predictions about the effects of changes in physical conditions.
Evaluate	Evaluate alternative explanations; and evaluate results of investigations with respect to sufficiency of data to support conclusions.
Draw Conclusions	Make valid inferences on the basis of observations, evidence, and/or understanding of physics concepts; and draw appropriate conclusions that address questions or hypotheses.

1. Asking questions based on observations—Scienti c inquiry includes observations of physical phenomena with unfamiliar characteristics or properties, and studying existing data sets in detail. ese observations, together with existing knowledge of physics concepts, lead to questions, which are used to formulate testable hypotheses to help answer those questions.
2. Generating evidence—Answering research questions and testing hypotheses requires designing and executing systematic investigations and controlled experiments (including identifying independent and dependent variables). Scientists must use their knowledge of physics concepts and physical phenomena to determine the appropriate approach to an investigation, including deciding on the evidence to be gathered, understanding what instrumentation and procedures are appropriate to use in data collection, and knowing the level of precision and accuracy needed in the data collection.
3. Working with data—Once the data are collected, scientists summarize the data in various types of visual displays. ey describe and summarize trends in the data, recognize patterns in the data, interpolate and extrapolate from the data, explore relationships between variables, and determine which patterns and relationships may be worth exploring further. In addition, they evaluate the data for consistency with predictions, and consider when revisions to the initial hypothesis might be needed.
4. Answering the research question—Scientists use evidence from observations and investigations together with science knowledge to answer the questions they have posed and support or refute hypotheses.
5. Making an argument from evidence—Scientists use evidence and understanding of physics concepts to develop explanations and models of physical phenomena, identify gaps or weaknesses in scienti c explanations or arguments, justify and support the reasonableness of their explanations, models, and conclusions, and extend these to new situations.

These science practices cannot be assessed in isolation, but must be assessed in the context of one of the TIMSS Advanced—Physics content domains, and drawing upon the range of thinking processes speci ed in the