TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY

TIMSS

TIMSS Advanced 2008 Assessment Frameworks

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International Association for the Evaluation of Educational Achievement

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TIMSS & PIRLS
International Study Center
Lynch School of Education, Boston College

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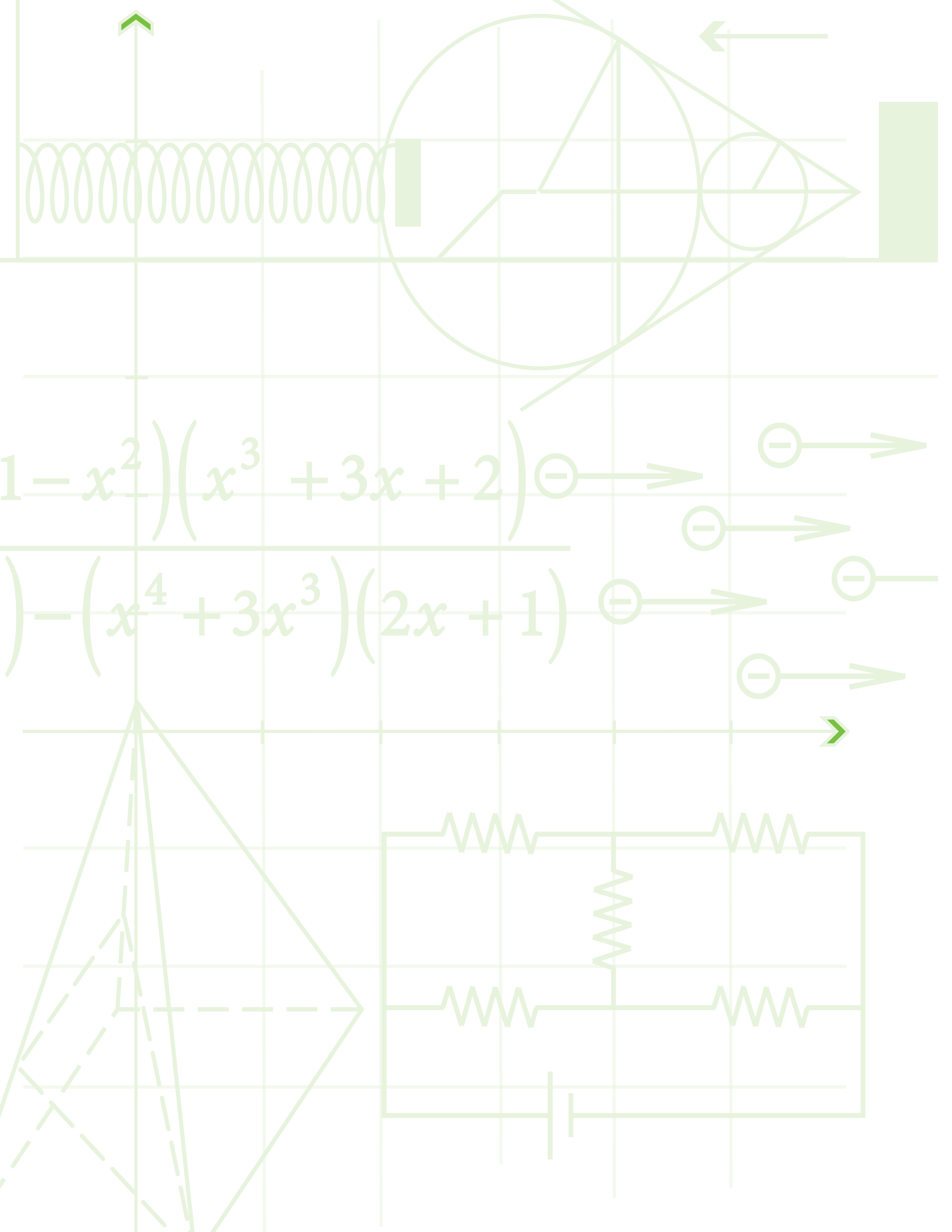


About TIMSS

IEA's Trends in International Mathematics and Science Study (TIMSS) provides valuable information about students' mathematics and science achievement in an international context. TIMSS assesses students at the fourth and eighth grades, and also collects a wealth of data from their schools and teachers about curriculum and instruction in mathematics and science. TIMSS findings have been used by many countries around the world in their efforts to improve teaching and learning mathematics and science in their schools.

Involving more than 60 countries, TIMSS 2007 is the most recent in the four-year cycle of studies to measure trends in students' mathematics and science achievement. The first TIMSS assessments were in 1995 in 41 countries, the second in 1999 involved 38 countries, and TIMSS 2003 involved more than 50 countries. The majority of countries participating in TIMSS 2007 will have trend data, some covering more than a decade back to 1995.

TIMSS Advanced 2008

First administered in 16 countries in 1995, TIMSS Advanced assesses school-leaving students with special preparation in advanced mathematics and physics. Since the 1995 assessment, however, TIMSS has not assessed students at the end of secondary school. Recognizing the strong link between scientific competence and economic productivity, and given the relatively long time period since the 1995 assessments, countries around the world have expressed interest in participating in TIMSS Advanced. They want internationally comparative data about the achievement of their students enrolled in advanced courses designed to lead into science-oriented programs in university. By joining TIMSS Advanced, countries that participated in 1995 can determine whether the achievement of students having taken advanced coursework has changed over time. Countries participating in TIMSS Advanced for the first time can assess the comparative standing in mathematics and physics in an international context.

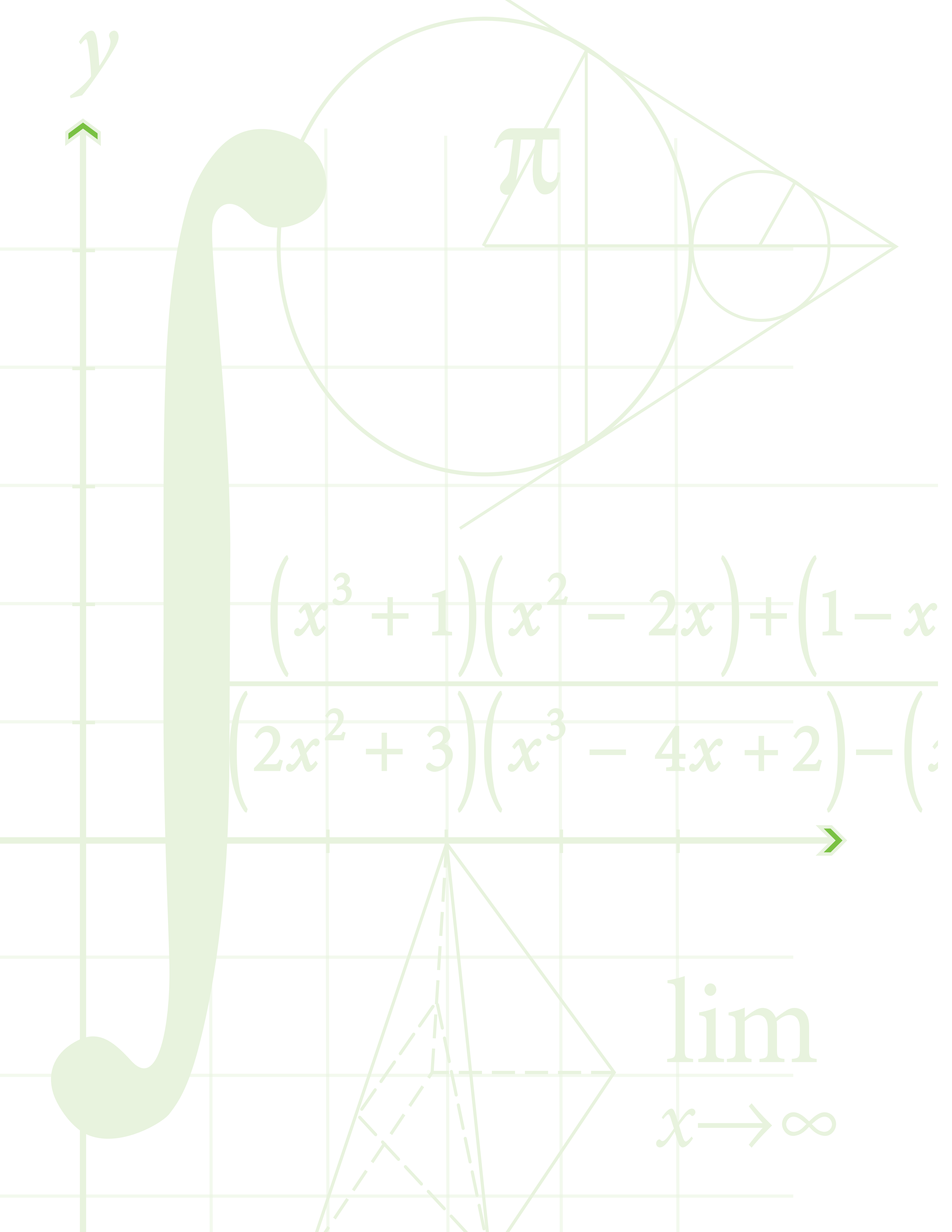
TIMSS uses the curriculum, broadly defined, as the major organizing concept in considering how educational opportunities are provided to students, and the factors that influence how students use these opportunities. To begin the process of defining the topics to be assessed in TIMSS Advanced, this document built on the composition of the 1995 Advanced Mathematics and Physics assessments to draft a Framework for TIMSS Advanced 2008. The description of cognitive domains also benefited from the TIMSS developmental project, funded by a number of countries, to enable reporting TIMSS 2007 results according to cognitive domains. The first draft of this document was thoroughly reviewed by participating countries, and updated accordingly. Countries provided feedback about the topics included in their curricula in advanced mathematics and physics courses, and made recommendations about the desirability and suitability of assessing particular topics.

Developing and Implementing TIMSS Advanced 2008

TIMSS, including TIMSS Advanced, is a major undertaking of the IEA. IEA has entrusted responsibility for the overall direction and management of the project to its TIMSS & PIRLS International Study Center at Boston College. In carrying out TIMSS, the TIMSS & PIRLS International Study Center works closely with the IEA Secretariat in Amsterdam on country membership and translation verification, the IEA Data Processing Center in Hamburg on database creation and documentation, Statistics Canada in Ottawa on sampling, and Educational Testing Service in Princeton, New Jersey on the psychometric scaling of the data. IEA is extremely grateful to Chinese Taipei and Norway, in particular, for providing support for TIMSS Advanced. The TIMSS Norwegian Team is playing a significant role in developing items for TIMSS Advanced. As in 1995, Svein Lie from Norway is the Physics Coordinator. Also, as in 1995, Bob Garden from New Zealand is the Advanced Mathematics Coordinator.

1

TIMSS Advanced 2008 Mathematics Framework



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Overview

The advanced mathematics assessment framework for TIMSS Advanced 2008 is organized around two dimensions: a content dimension specifying the domains or subject matter to be assessed within mathematics (i.e., algebra, calculus, and geometry) and a cognitive dimension specifying the domains or thinking processes to be assessed (i.e., knowing, applying, and reasoning). The cognitive domains describe the sets of behaviors expected of students as they engage with the mathematics content. Exhibit 1 shows the target percentages of testing time devoted to each content and cognitive domain for the advanced mathematics assessment.

Exhibit 1: Target Percentages for the TIMSS Advanced Mathematics Assessment Devoted to Content and Cognitive Domains

Content Domains	Percentages
Algebra	35%
Calculus	35%
Geometry	30%
Cognitive Domains	**Percentages**
Knowing	35%
Applying	35%
Reasoning	30%

Advanced Mathematics Content Domains

Essentially, the TIMSS 2008 Advanced Mathematics assessment consists of the traditional areas of algebra, functions, calculus, geometry, and trigonometry. The first category, *algebra*, includes much of the algebra and functions content that provides the foundation for mathematics at the college or university level. Topics from these areas occupy a substantial amount of the time devoted to pre-university mathematics.

Since *calculus* is a central tool in understanding the principles governing the physical world, it plays a major role in advanced mathematics curricula at this level and merits significant emphasis. Calculus is the principal point of entry to most mathematically-based scientific careers.

Students intending to study university-level mathematics also should develop an understanding of various components of *geometry*. Applications of geometry are tied directly to the solution of many real-world problems and are used extensively in the sciences. Since trigonometry has its origins in the study of triangle measurement, the geometry content domain also includes elements of trigonometry.

The description of content domains for TIMSS Advanced 2008 takes into account changes in advanced mathematics curricula since 1995 and, in addition, concentrates the assessment on those content areas for which valid and reliable measurements can be made with confidence.

Even though five content domains were included in 1995, the three major domains were *number*, *equations*, *and functions*; *calculus*; and *geometry,* whereas probability and statistics and *validation and structure* had very few items, insufficient for reporting. Items similar to those classified in validation and structure in 1995 will be included as part of the other content domains. For probability and statistics, wide variation across countries in both content and depth of study makes it very challenging to include that content area in the TIMSS 2008 Advanced Mathematics Study.

In the following paragraphs, the three content domains are defined in terms of the specific mathematical topics to be included in the TIMSS 2008 Advanced Mathematics assessment. The definition of each content domain includes a list of broad objectives covered in the mathematics curriculum in the majority of participating countries. These objectives are presented in terms of student knowledge or the abilities that items aligned with the objectives are designed to elicit.

Algebra

Students studying pre-university mathematics should be able to make use of properties of the real and complex number systems to solve problems set in real world contexts or in abstract, mathematical ones. They should also have facility in investigating basic characteristics of sequences and series, and skill in manipulating and using combinations and permutations. The ability to work with a variety of equations also is fundamental for such students, providing a means of operating with mathematical concepts at an abstract level. The concept of function is an important unifying idea in mathematics.

1. Perform operations with complex numbers.
2. Determine the n^{th} term of numeric and algebraic series, and the sums to n terms or infinity of series.
3. Solve straightforward problems involving permutations, combinations, and probability.
4. Solve linear, simultaneous, and quadratic equations and inequalities. Indicate whether a value (or values) satisfies a given equation or inequality. Solve surd (radical) equations, logarithmic, and exponential equations.
5. Recognize and generate equivalent representations of functions as ordered pairs, tables, graphs, formulas, or words.
6. Determine signs and values of functions, including rational

functions, for given values and ranges of the variable. Evaluate a function of a function.

Calculus

The content in this domain underpins many of the important theoretical and practical applications of mathematics in a wide range of scientific areas and the solution of problems in many and varied situations. Students having taken advanced mathematics should demonstrate the skills, concepts, and processes acquired from the successful study of differential and integral calculus.

Since the calculus content of national and local advanced mathematics curricula varies considerably across countries, the calculus content for TIMSS Advanced Mathematics 2008 has been limited to material likely to be included in final year mathematics in almost all of the participating countries. The focus is on understanding limits and finding the limit of a function, differentiation and integration of a range of functions, and using these skills in solving problems.

1. Evaluate limits of functions, including rational functions. Know the conditions for continuity and differentiability of functions.
2. Differentiate polynomial, exponential, logarithmic, trigonometric, rational, radical, composite, and parametric functions. Differentiate products and quotients.
3. Use derivatives to solve problems (e.g., in kinematics, optimization, and rates of change).
4. Use first and second derivatives to determine gradient, turning points, and points of inflection of polynomial and rational functions, and sketch and interpret graphs of functions.
5. Integrate polynomial, exponential, trigonometric, and rational functions. Evaluate definite integrals, and apply integration to compute the area under a curve.

Geometry

Geometry equips students to utilize relations between points, lines, shapes, and properties of figures to solve problems and model physical situations. However, approaches to teaching content in this domain at this level varies across countries. Because of this, it is important to be clear about what strands or topics have been included in this domain for TIMSS Advanced 2008.

The TIMSS geometry items relate to four strands or topics: Euclidean geometry (traditional or transformation), analytic geometry, trigonometry, and vectors. Euclidean geometry and analytic geometry have been important components of the secondary mathematics curriculum for centuries and are still widely viewed as important prerequisites to the study of mathematics at the university level. Trigonometry is part of the mathematics curriculum in all countries, but not always as part of the geometry domain. Transformational geometry and vectors are more recent additions to the mathematics curriculum in many countries, and there is considerable variation both in the amount of emphasis given to them across countries, as well as in the degree of rigor with which the area is approached. The TIMSS items related to these two areas deal with fairly elementary topics.

1. Use the properties of geometric figures to solve problems. Prove straightforward geometric propositions in two and three dimensions.
2. Use gradients, y-axis intercepts, and points of intersection of straight lines in the Cartesian plane in solving problems.
3. Know and apply the equations and properties of circles in the Cartesian plane. Derive tangents and normals to given points on a circle.
4. Use trigonometry to solve problems involving triangles. Know the properties of sine, cosine, and tangent graphs, and solve straightforward equations involving these functions.
5. Apply the properties of vectors and their sums and differences to solve problems.

As in TIMSS 1995, students participating in the TIMSS 2008 Advanced Mathematics assessment will be permitted to use calculators for the entire assessment. However, it is noted that there have been tremendous changes in calculator technology since 1995.

Advanced Mathematics Cognitive Domains

To respond correctly to TIMSS test items, students need to be familiar with the mathematics content being assessed, but they also need to draw on a range of cognitive skills. Describing these skills is an essential aspect of developing the assessment of achievement in Advanced Mathematics because this ensures that the important cognitive goals of school mathematics education are surveyed across the content domains already defined.

A central aim of school mathematics programs at all levels is to have students understand the subject matter of the courses they are studying. Understanding a mathematics topic consists of having the ability to operate successfully in three cognitive domains. The first domain, *knowing*, covers the facts, procedures, and concepts students need to know, while the second, *applying*, focuses on the ability of students to make use of this knowledge to select or create models and solve problems. The third domain, *reasoning*, goes beyond the solution of routine problems to encompass the ability to use analytical skills, generalize, and apply mathematics to unfamiliar or complex contexts.

Each content domain will include items developed to address each of the three cognitive domains. For example, the algebra domain will include knowing, applying, and reasoning items, as will the other content domains.

Knowing

Facility in using mathematics or reasoning about mathematical situations depends on mathematical knowledge and familiarity with mathematical concepts. The more relevant knowledge a student is able to recall and the wider the range of concepts he or she has understood, the greater the potential for engaging in a wide range of problem-solving situations and for developing mathematical understanding.

Without access to a knowledge base that enables easy recall of the language and basic facts and conventions of number, symbolic representation, and spatial relations, students would find purposeful mathematical thinking impossible. *Facts* encompass the factual knowledge that provides the basic language of mathematics, and the essential mathematical facts and properties that form the foundation for mathematical thought.

Procedures form a bridge between more basic knowledge and the use of mathematics for solving routine problems, especially those encountered by many people in their daily lives. In essence, a fluent use of procedures entails recall of sets of actions and how to carry them out. Students need to be efficient and accurate in using a variety of computational procedures and tools. They need to see that particular procedures can be used to solve entire classes of problems, not just individual problems.

Knowledge of *concepts* enables students to make connections between elements of knowledge that, at best, would otherwise be retained as isolated facts. It allows them to make extensions beyond their existing knowledge, judge the validity of mathematical statements and methods, and create mathematical representations.

	Behaviors Included in the Knowing Domain	
1	**Recall**	Recall definitions, terminology, notation, mathematical conventions, number properties, geometric properties.
2	**Recognize**	Recognize entities that are mathematically equivalent (e.g., different representations of the same function or relation).
3	**Compute**	Carry out algorithmic procedures (e.g., determining derivatives of polynomial functions, solving a simple equation).
4	**Retrieve**	Retrieve information from graphs, tables, or other sources.

Applying

Problem solving is a central goal, and often a means, of teaching mathematics, and hence this and supporting skills (e.g., select, represent, model) feature prominently in the domain of *applying* knowledge. In items aligned with this domain, students need to apply knowledge of mathematical facts, skills, procedures, and concepts to create representations and solve problems. Representation of ideas forms the core of mathematical thinking and communication, and the ability to create equivalent representations is fundamental to success in the subject.

Problem settings for items in the applying domain are more routine than those aligned with the reasoning domain and will typically have been standard in classroom exercises designed to provide practice in particular methods or techniques. Some of these problems will have been expressed in words that set the problem situation in a quasi-real context. Though they range in difficulty, each of these types of "textbook" problems is expected to be sufficiently familiar to students that they will essentially involve selecting and applying learned procedures.

Problems may be set in real-life situations or may be concerned with purely mathematical questions involving, for example, numeric or algebraic expressions, functions, equations, geometric figures, or statistical data sets. Therefore, problem solving is included not only in the *applying* domain, with emphasis on the more familiar and routine tasks, but also in the *reasoning* domain.

	Behaviors Included in the Applying Domain	
1	**Select**	Select an efficient/appropriate method or strategy for solving a problem where there is a commonly used method of solution.
2	**Represent**	Generate alternative equivalent representations for a given mathematical entity, relationship, or set of information.
3	**Model**	Generate an appropriate model such as an equation or diagram for solving a routine problem.
4	**Solve Routine Problems**	Solve routine problems, (i.e., problems similar to those students are likely to have encountered in class). For example, differentiate a polynomial function, use geometric properties to solve problems.

Reasoning

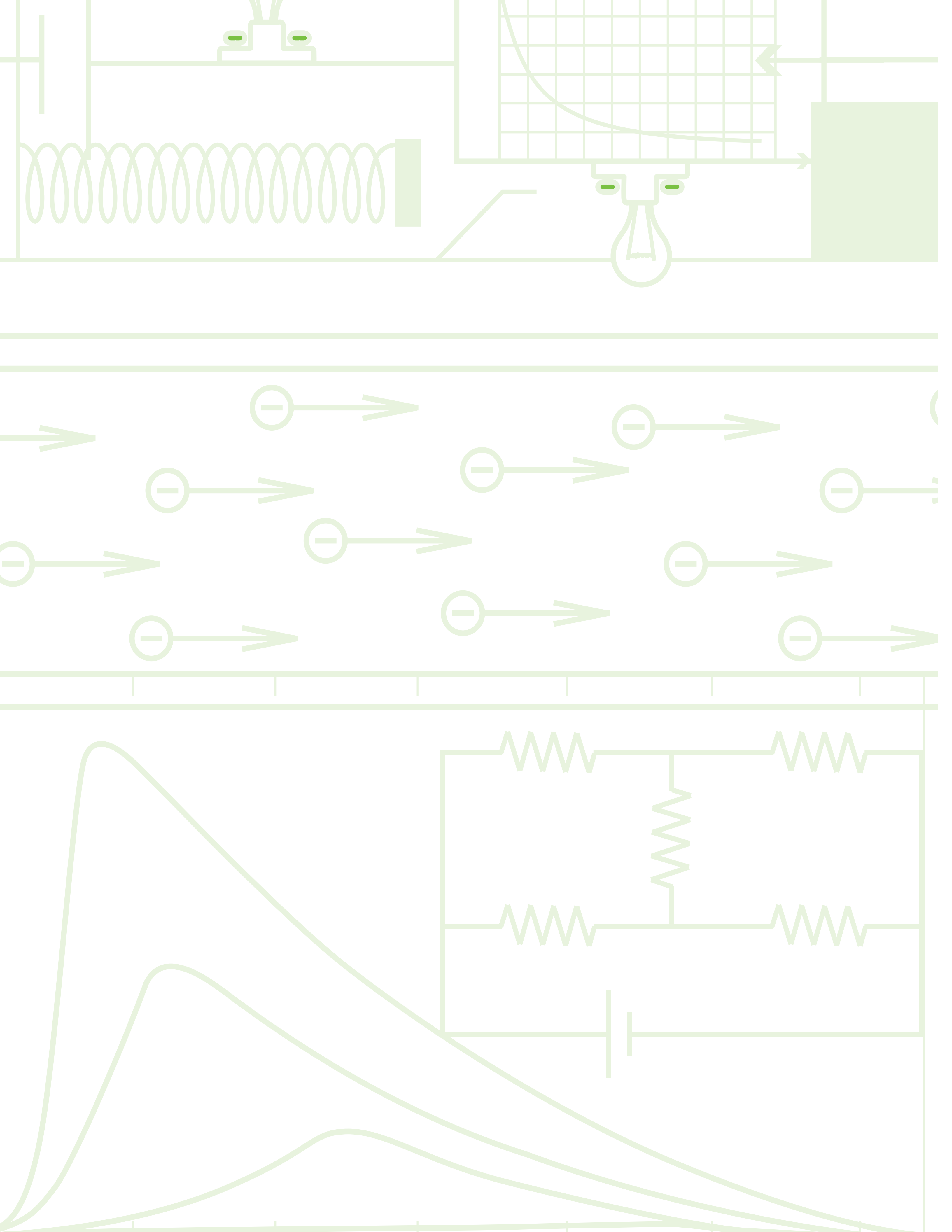
Reasoning mathematically involves the capacity for logical, systematic thinking. It includes intuitive and inductive reasoning based on patterns and regularities that can be used to arrive at solutions to non-routine problems. Non-routine problems are problems that are very likely to be unfamiliar to students. They make cognitive demands over and above those needed for solution of routine problems, even when the knowledge and skills required for their solution have been learned. Non-routine problems may be purely mathematical or may have real-life settings. Both types of items involve transfer of knowledge and skills to new situations, and interactions among reasoning skills are usually a feature. Problems requiring reasoning may do so in different ways. Reasoning may be involved because of the novelty of the context or the complexity of the situation, or because any solution to the problem must involve several steps, perhaps drawing on knowledge and understanding from different areas of mathematics.

Even though many of the behaviors listed within the reasoning domain are those that may be drawn on in thinking about and solving novel or complex problems, each by itself represents a valuable outcome of mathematics education, with the potential to influence learners' thinking more generally. For example, reasoning involves the ability to observe and make conjectures. It also involves making logical deductions based on specific assumptions and rules, and justifying results.

Behaviors Included in the Reasoning Domain		
1	**Analyze**	Investigate given information, and select the mathematical facts necessary to solve a particular problem. Determine and describe or use relationships between variables or objects in mathematical situations. Make valid inferences from given information.
2	**Generalize**	Extend the domain to which the result of mathematical thinking and problem solving is applicable by restating results in more general and more widely applicable terms.
3	**Synthesize/ Integrate**	Combine (various) mathematical procedures to establish results, and combine results to produce a further result. Make connections between different elements of knowledge and related representations, and make linkages between related mathematical ideas.
4	**Justify**	Provide a justification for the truth or falsity of a statement by reference to mathematical results or properties.
5	**Solve Non-routine Problems**	Solve problems set in mathematical or real-life contexts where students are unlikely to have encountered similar items, and apply mathematical procedures in unfamiliar or complex contexts.

2

TIMSS Advanced 2008 Physics Framework



Overview

Similar to advanced mathematics, the physics assessment framework for TIMSS Advanced 2008 is organized around two dimensions: a content dimension specifying the domains or subject matter to be assessed within physics (i.e., mechanics, electricity and magnetism, heat and temperature, and atomic and 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 sets of behaviors expected of students as they engage with the physics content. Exhibit 2 shows the target percentages of testing time devoted to each content and cognitive domain for the physics assessment.

Exhibit 2: Target Percentages for the TIMSS Advanced 2008 Physics Assessment Devoted to Content and Cognitive Domains

Content Domains	Percentages
Mechanics	30%
Electricity and Magnetism	30%
Heat and Temperature	20%
Atomic and Nuclear Physics	20%
Cognitive Domains	**Percentages**
Knowing	30%
Applying	40%
Reasoning	30%

Physics Content Domains

The TIMSS Advanced 2008 physics assessment consists of four content domains: *mechanics*, *electricity* and *magnetism*, *heat* and *temperature*, and *atomic and nuclear physics*. The 1995 assessment also included a fifth content domain, wave phenomena. However, in the 2008 framework, topics from this domain were incorporated into the other four domains. Also, *atomic and nuclear physics* was called *modern physics* in 1995.

Mechanics

Mechanics can be regarded as the foundation of physics, since ideas of forces and motion are fundamental also to other areas of physics. Newton's three laws of motion together with the law of gravitation provide the elements of this domain. Some basic features of relativity are included since Einstein's theory is a significant extension of the classical Newtonian version of mechanics.

1. Demonstrate basic understanding of the conditions for equilibrium (i.e., Newton's first and third law, the role of torque and forces in equilibrium) and the dynamics of different types of movement (i.e., the concept of pressure in liquids).
2. Demonstrate understanding of kinetic and potential energy (gravitational and elastic). Apply the notion of conservation of mechanical energy in relevant situations.
3. Apply knowledge of mechanical wave phenomena in sound, water, and strings. Use knowledge of the relationship between speed, frequency, and wavelength in problem situations. Demonstrate understanding of refraction.
4. Identify forces, including frictional force, acting on a body moving with constant acceleration and explain how their combined action influences the body's movement. Apply Newton's laws to carry out relevant calculations (e.g., of speed and acceleration).

5. Apply understanding of circular motion to find forces acting on a body moving in a circular path, and calculate the body's centripetal acceleration, speed, and circling time. Apply the law of gravitation to analyze and calculate aspects of the movements of planets (e.g., distance from Sun, circling time).
6. Demonstrates understanding of *elastic* and *inelastic* collisions. Apply the law of conservation of momentum in various collision situations and the law of conservation of mechanical (i.e., kinetic) energy for perfectly elastic collisions.
7. Demonstrate understanding of simple aspects of relativity (e.g., length contraction and time dilatation for an object moving with constant speed in relation to the observer).

Electricity and Magnetism

Phenomena related to electricity and magnetism are integral to everyday life. In particular, electricity is crucial for industry, business, and the home, providing energy in the form of heating, lighting, and power for a range of electric and electronic devices. The role of magnetism is less obvious, but through the connection between magnetism and electricity, magnetic phenomena are crucial for energy transformation and transfer and our everyday electronic surroundings. The close relationship between electricity and magnetism is apparent in electromagnetic radiation, with visible light an example of a particular interval of wave frequencies.

1. Calculate the magnitude and direction of the electrostatic attraction or repulsion between isolated charged particles by application of Coulomb's law. Predict the force on and the path of a charged particle in a homogeneous electric field.
2. Demonstrate a thorough grasp of electrical circuits, including application of Ohm's law and Joule's law of power consumption for complex electrical circuits and for separate components of a circuit.

3. Analyze the magnitude and direction of the force on a charged particle in a magnetic field. Demonstrate understanding of the relationship between magnetism and electricity in phenomena such as magnetic fields around electric conductors, electromagnets, and electromagnetic induction. Apply Faraday's and Lenz' laws of induction in problem situations.
4. Demonstrate understanding of electromagnetic radiation in terms of waves caused by the interplay between variations in electric and magnetic fields. Identify various types of waves (radio, infrared, x-rays, light, etc.) by wavelength and frequency.

Heat and Temperature

Heat and temperature are distinct concepts: heat is energy and as such can be transferred by many mechanisms, whereas temperature may be regarded as a measure of kinetic energy for molecules. Heat transfer from the Sun and between bodies of water, land mass, and atmosphere is the underlying cause of weather and climate on Earth. At varied temperatures, substances appear in the form (or phase) of solid, liquid, or gas. The strength and wavelengths of heat radiation is strongly dependent on the temperature of the radiating body. Thus, the color of radiating (not so for reflecting) objects can tell us about their surface temperature.

1. Distinguish between *heat* and *temperature,* and identify the three forms of heat transfer: convection, radiation, and conduction. Apply understanding of heat transfer and specific heat capacities to predict equilibrium temperature when bodies of different temperature are brought together. Apply knowledge of evaporation and condensation.
2. Relate expansion of solids and liquids to temperature change. Apply the laws of ideal gases (in the form pV/T = constant) in problem situations, and understand the limitations of these laws. Apply the first law of thermodynamics in simple situations.

3. Demonstrate basic understanding of heat ("black body") radiation and its dependence on temperature. Estimate the temperature of a body from the color of its radiation, and describe the fundamental principle behind the "greenhouse" effect on Earth.

Atomic and Nuclear Physics

This content domain covers much of what is sometimes known as *modern physics*, since the relevant theories and experiments were published during the last 100 years or so. The exploration of the atom and its nucleus opened a microscopic world of physics where many of the classical laws and concepts are no longer relevant.

1. Describe the structure of the atom and its nucleus in terms of electrons, protons, and neutrons. Apply knowledge of atomic number and atomic mass number in problem situations.
2. Relate light emission and absorption in the spectrum to the behavior of electrons. Apply understanding of the photoelectric effect in problem situations. Explain the process of x-ray emission by acceleration of electrons.
3. Distinguish between types of nuclear reactions (i.e., fission, fusion, and radioactive decay), and discuss their role in nature (e.g., in stars) and society (e.g., reactors, bombs). Demonstrate basic understanding of radioactive isotopes, their half-lives, and their harmful effects on humans.

Physics Cognitive Domains

To respond correctly to the TIMSS physics items, students need to be familiar with the physics content being assessed, but they also need to draw on a range of cognitive skills. Articulating these skills is crucial to the development of an assessment like TIMSS Advanced, since they are vital in ensuring that the items address the important cognitive aims of school physics education across the content domains already outlined.

The cognitive dimension is divided into three domains based on what students have to know and do when confronting the various physics items developed for the TIMSS Advanced assessment. The first domain, *knowing*, covers facts, procedures, and concepts students need to know for a solid foundation in physics. The second domain, *applying*, focuses on the ability of the student to apply knowledge and conceptual understanding in a straightforward problem situation. The third domain, *reasoning*, goes beyond the solution of routine problems to encompass unfamiliar situations, complex contexts, and multi-step problems.

While some hierarchy is imposed in the division of behaviors into the three cognitive domains, a range of difficulty levels is expected for items developed for each of the cognitive domains. The following sections further describe the student skills and abilities defining the cognitive domains. The general descriptions are followed by lists of specific behaviors to be elicited by items that are aligned with each domain.

Each content domain will include items developed to address each of the three cognitive domains. For example, the *mechanics* domain will include knowing, applying, and reasoning items, as will the other content domains.

Knowing

Knowing refers to students' knowledge base of physics facts, information, concepts, tools, and procedures. Accurate and broad-based factual knowledge enables students to engage successfully in the more complex cognitive activities essential to the scientific enterprise. Students are expected to recall or recognize accurate physics statements; possess knowledge of vocabulary, facts, information, symbols, units, and procedures; and select appropriate apparatus, equipment, measurement devices, and experimental operations to use in conducting investigations.

	Behaviors Included in the Knowing Domain	
1	**Recall**	Make or identify accurate statements about science facts, relationships, processes, and concepts. Recognize and use scientific vocabulary, symbols, abbreviations, units, and scales in relevant contexts.
2	**Describe**	Describe physical materials and processes demonstrating knowledge of properties, structure, function, and relationships.

Applying

The questions addressing this cognitive domain are designed to involve the application of knowledge of physics facts, concepts, and procedures in straightforward problem situations. To measure *applying*, TIMSS Advanced will include physics items that require students to apply their understanding of physics concepts and principles to find a solution or develop an explanation. Items aligned with this cognitive domain will involve the application or demonstration of relationships, equations, and formulas in contexts likely to be familiar in the teaching and learning of physics concepts. Both quantitative problems requiring a numerical solution and qualitative problems requiring a written descriptive response are included. In providing explanations, students should be able to use diagrams or models to illustrate structures and relationships and demonstrate knowledge of physics concepts.

	Behaviors Included in the Applying Domain	
1	**Relate**	Relate knowledge of an underlying physical concept to an observed or inferred property, behavior, or use of objects or materials.
2	**Use Models**	Use a diagram or model to demonstrate understanding of a physics concept, structure, relationship, process, or system (e.g., electrical circuit, atomic structure).
3	**Find Solutions**	Identify or use a physical relationship, equation, or formula to find a qualitative or quantitative solution involving the direct application/demonstration of a concept.
4	**Explain**	Provide or identify an explanation for an observation or natural phenomenon that demonstrate understanding of the underlying physics concept, principle, law, or theory.

Reasoning

A major purpose of physics education is to prepare students to engage in scientific reasoning to solve problems, develop explanations, draw conclusions, and extend their knowledge to new situations. In addition to the more direct applications of physics concepts exemplified in the applying domain, problem-solving situations in the reasoning domain involve unfamiliar or more complicated contexts that require students to reason from scientific principles to provide an answer. Solutions may involve breaking down a problem into component parts, each involving the application of a physics concept or relationship. Students may be required to analyze a problem to determine what underlying principles are involved; devise and explain strategies for problem solving; select and apply appropriate equations, formulas, relationships, or analytical techniques; and evaluate their solutions. Correct solutions to such problems may stem from a variety of approaches or strategies, and developing the ability to consider alternative strategies is an important educational goal in the teaching and learning of physics.

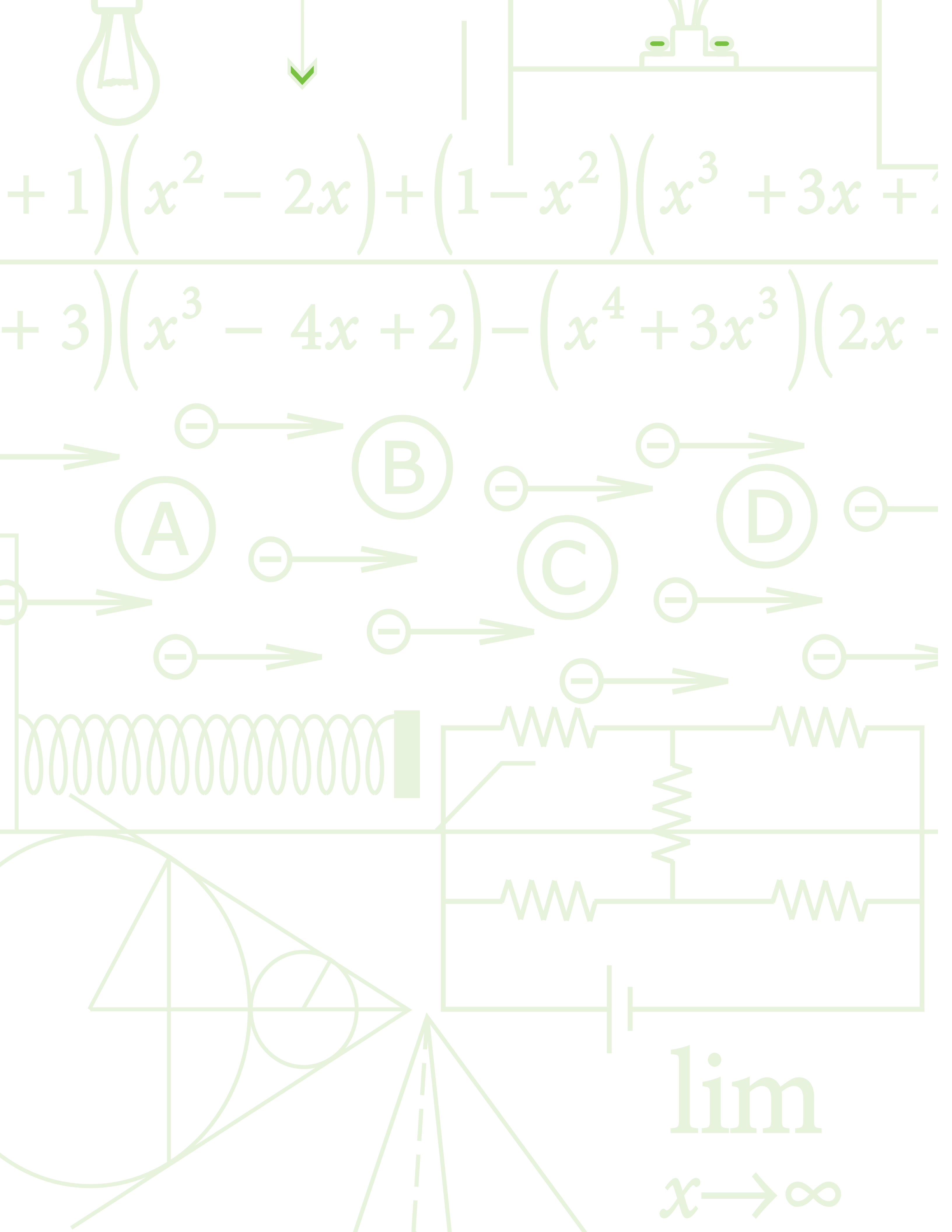
Students may be required to draw conclusions from physics data and facts, weigh advantages and disadvantages of alternative materials and processes, and evaluate solutions to problems. Considerable scientific reasoning also is involved in developing hypotheses and designing scientific investigations to test them, and in analyzing and interpreting data.

	Behaviors Included in the Reasoning Domain	
1	**Analyze/ Solve Problems**	Analyze problems to determine the relevant relationships, concepts, and problem-solving steps. Develop and explain problem-solving strategies.
2	**Generalize**	Make general conclusions that go beyond the experimental or given conditions, apply conclusions to new situations, and determine general formulas for expressing physical relationships.

3	**Synthesize/ Integrate**	Provide solutions to problems that require consideration of a number of different factors or related concepts. Make associations or connections between concepts in different areas of physics. Integrate mathematical concepts or procedures in the solution to physics problems.
4	**Justify**	Use evidence and scientific understanding to justify explanations and problem solutions. Construct arguments to support the reasonableness of solutions to problems, conclusions from investigations, or scientific explanations.
5	**Hypothesize/ Predict**	Formulate hypotheses as testable assumptions using knowledge from observation and/or analysis of scientific information and conceptual understanding. Make predictions about the effects of changes in physical conditions in light of evidence and conceptual understanding.
6	**Draw Conclusions**	Detect patterns in data, describe or summarize data trends, and interpolate or extrapolate from data or given information. Make valid inferences on the basis of evidence and/or understanding of physics concepts.

3

TIMSS Advanced 2008 Assessment Design



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Overview

The TIMSS Advanced 2008 assessment measures student achievement in advanced mathematics and physics at the end of secondary schooling. TIMSS Advanced also reports student achievement in the major content and cognitive domains of the two subjects. These ambitious coverage and reporting goals will provide valuable information for educators and policy makers, but pose significant challenges for data collection, analysis, and reporting.

A consequence of the TIMSS Advanced reporting goals is that there are more items in the assessment than can be reasonably given to a student in the amount of testing time available. Accordingly, TIMSS Advanced uses a matrix-sampling approach that assembles the pool of achievement items in advanced mathematics and physics into a set of eight assessment booklets – four advanced mathematics and four physics booklets – with each student completing one booklet only. Most items appear in more than one booklet, providing a mechanism for linking the student responses from the various booklets. Booklets are distributed among sampled students so that the groups of students responding to each booklet are approximately equivalent in terms of student ability.

Target Population Definitions

TIMSS Advanced plans to assess the advanced mathematics and physics achievement of students in the final year of secondary schooling. This is the 12th year of formal schooling in most countries. The target population definition for advanced mathematics is as follows:

> *Students in the final year of secondary schooling who have taken courses in advanced mathematics.*

Similarly, for physics the target population definition is:

> *Students in the final year of secondary schooling who have taken courses in physics.*

The decision as to which mathematics or physics courses should be included in defining the target population is a matter for each participating country. In general, the courses included should be those taken by the most advanced students, typically those planning further study in mathematics or physics at university or other institutes of higher education. Courses should cover most of the advanced mathematics and physics content topics specified in this framework document.

Depending on their course-taking experiences, students in the final year of schooling may belong to the advanced mathematics target population, the physics target population, or both. Students who belong to both populations will be randomly assigned either an advanced mathematics booklet or a physics booklet.

Item Blocks

To facilitate the process of creating assessment booklets, TIMSS Advanced assembles the assessment items into item blocks, with each item block consisting of approximately 10 items and requiring 30 minutes of assessment time. TIMSS Advanced consists of 14 item blocks in total, seven blocks of advanced mathematics items and seven blocks of physics items. Student booklets are assembled from various combinations of these item blocks.

Of the 14 item blocks in the TIMSS Advanced 2008 assessment, six blocks consist of trend items (items that were used in the 1995 assessment) and eight blocks consist of new items developed for the 2008 assessment. As shown in Exhibit 3, the advanced mathematics blocks are labeled M1 to M7, and the physics blocks are labeled P1 to P7. The labels shown in parentheses are the block labels used in 1995, where blocks I and E were 30-minute blocks and blocks J and F were 60-minute blocks. Advanced mathematics blocks K and L from 1995, each containing 60 minutes of items, were released for public use when the results of the study were published. These are replaced in 2008 by four 30-minute blocks, M4 through M7. Similarly, two 60-minute physics blocks, G and H, were released and are replaced by blocks P4 through P7.

Exhibit 3: TIMSS Advanced 2008 Block Design

Advanced Mathematics Blocks	Source of Items	Physics Blocks	Source of Items
M1 (I)	*Block I from 1995*	P1 (E)	*Block E from 1995*
M2 (J1)	*1st half block J – 1995*	P2 (F1)	*1st half block F – 1995*
M3 (J2)	*2nd half block J – 1995*	P3 (F2)	*2nd half block F – 1995*
M4	*New items for 2008*	P4	*New items for 2008*
M5	*New items for 2008*	P5	*New items for 2008*
M6	*New items for 2008*	P6	*New items for 2008*
M7	*New items for 2008*	P7	*New items for 2008*

In 2008, the 1995 item blocks J and F each are split into two 30-minute blocks and relabeled M2, M3 and P2, P3, respectively. Thus, the 2008 assessment consists exclusively of 30-minute item blocks, and all will be rotated. As in 1995, the 14 blocks of items contain an estimated seven hours of testing time; 3½ hours for advanced mathematics and 3½ hours for physics. The assessment time allotted for each student booklet, however, is limited to 90 minutes, or three item blocks.

Booklet Design

The assignment of item blocks to student assessment booklets is designed to maximize coverage of the framework while ensuring that each student responds to sufficient items to provide reliable measurement of trends in advanced mathematics and physics. A further objective is to ensure that trends in content and cognitive domains are measured reliably. To enable linking among booklets while keeping the number of booklets to a minimum, most item blocks appear in two booklets.

The 14 item blocks are distributed across eight student assessment booklets, as shown in Exhibit 4.

Exhibit 4: TIMSS Advanced 2008 Booklet Design

	Booklet	Assessment Blocks		
		Part 1	Part 2	Part 3
Advanced Mathematics	**1**	M1	M2	M3
	2	M4	M3	M5
	3	M6	M4	M1
	4	M2	M5	M7
Physics	**5**	P1	P2	P3
	6	P4	P3	P5
	7	P6	P4	P1
	8	P2	P5	P7

The block-booklet assignment is identical for advanced mathematics and physics. Each student booklet consists of three item blocks, all either advanced mathematics blocks (booklets 1, 2, 3, and 4) or physics blocks (booklets 5, 6, 7, and 8). Booklets 1 (advanced mathematics) and 5 (physics) consist entirely of trend blocks and are identical to their 1995 counterparts (booklets 3A and 2A respectively). All other booklets consist of one trend block and two new blocks. Blocks M1 through M5 and P1 through P5 each appear in two booklets, in a different position in each booklet (first, second, or third). Advanced mathematics blocks M6 and M7 and physics blocks P6 and P7 each appear in one booklet only.

Question Types and Scoring Procedures

Student achievement in advanced mathematics and physics is assessed through a range of items in each subject. Two item formats are used in the TIMSS Advanced assessment: multiple-choice and constructed-response. At least half of the total number of score points come from multiple-choice items, each multiple-choice item being worth one score point. The remaining score points come from constructed-response items. Constructed-response items generally are worth one or two score points, depending on the nature of the task and the skills required in completing them.

Release Policy

Based on the TIMSS Advanced 2008 design, eight of the 14 item blocks are released when the assessment results for 2008 are published, and the remaining six blocks are kept secure for use in future assessments. The released blocks include four trend blocks (blocks M1 and M3 for advanced mathematics and blocks P1 and P3 for physics) and four new blocks (blocks M6 and M7 for advanced mathematics and blocks P6 and P7 for physics). Thus, advanced mathematics blocks M2, M4, and M5, and physics blocks P2, P4, and P5 are retained as secure trend blocks for the next cycle of TIMSS Advanced.

Background Questionnaires

An important purpose of TIMSS Advanced is to study the educational context within which students learn advanced mathematics and physics. To collect information useful in interpreting student achievement in participating countries, TIMSS Advanced plans a series of questionnaires for curriculum specialists, school principals, mathematics and physics teachers, and the students themselves.

Curriculum Questionnaires

At earlier grades (fourth and eighth), TIMSS has successfully collected information about the intended curriculum using mathematics and science curriculum questionnaires completed by the National Research Coordinator, usually in concert with curriculum specialists and educators in these subjects. The questionnaires are designed to collect basic information about the organization of the mathematics and science curriculum in each country, and about the content in these subjects intended to be covered up to the fourth and eighth grades. A similar approach is planned for TIMSS Advanced, with separate curriculum questionnaires for advanced mathematics and physics. These could provide valuable internationally-comparable information about the topics intended to be covered in the courses taken by students of advanced mathematics and physics. The curriculum questionnaires also could provide information on the size of the cohort of students that make up the advanced mathematics and physics populations in each country and the courses that they have taken in these subjects.

School Questionnaire

Completed by the principal (or designee) of each school, the school questionnaire asks about resources available to support advanced mathematics and physics instruction, school organization and instructional time, and school environment and climate for learning. It is designed to take about 30 minutes.

Teacher Questionnaires

The most important source of information about how the curriculum is taught in schools (the "implemented curriculum" in IEA parlance) is, of course, the classroom teacher. At fourth and eighth grades, TIMSS has collected very valuable data on curriculum coverage and instructional practices in mathematics and science through teacher questionnaires. Teachers of the students participating in the TIMSS assessments provide information about what topics their students have studied and the instructional approaches used. Questionnaires for teachers of advanced mathematics or physics have the potential to provide extremely useful information about classroom coverage of topics in these subjects, and about instructional approaches and practices. Whether or not it is practical to include questionnaires for teachers in TIMSS Advanced depends to some extent on how schools in participating countries are organized to teach advanced mathematics and physics. Identifying the teachers of students of these subjects may be more straightforward in countries with highly-tracked educational systems, but may pose more difficulties where students can choose from a wide variety of course offerings.

Student Questionnaires

Each student who participates in the TIMSS Advanced assessment will complete a questionnaire. The questionnaires for the advanced mathematics and physics assessments will ask about aspects of students' home and school lives, including educational resources and home educational supports, educational experiences and aspirations, classroom activities related to mathematics and physics instruction, self-perception and attitudes about mathematics and physics, homework and out-of-school activities, computer use, and basic demographic information. The student questionnaires require about 30 minutes to complete.

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