CHAPTER 14

Using Scale Anchoring to Interpret the TIMSS Advanced 2015 Achievement Scales

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Introduction

As described in Chapter 13: Scaling the TIMSS Advanced 2015 Achievement Data, the TIMSS Advanced 2015 achievement results are summarized using item response theory (IRT) scaling and reported on 0 to 1,000 achievement scales, with most achievement scores ranging from 300 to 700. Countries' average scores provide users of the data with information about how achievement compares among countries and whether scores are improving or declining over time.

To provide important information for policy and curriculum reform, however, it is important to understand the advanced mathematics and physics competencies associated with different locations within the range of scores on the achievement scales. For example, in terms of levels of student understanding, what does it mean for a country to have average achievement of 513 or 426, and how are these scores different?

The TIMSS Advanced 2015 International Benchmarks provide information about what students know and can do at different points along the achievement scales. More specifically, TIMSS Advanced has identified three points along the achievement scales to use as international benchmarks of achievement—Advanced International Benchmark (625), High International Benchmark (550), and Intermediate International Benchmark (475). For each assessment, the TIMSS & PIRLS International Study Center works with the expert international committee, Science and Mathematics Item Review Committee (SMIRC), to conduct a scale anchoring analysis to describe student competencies at the benchmarks.

This chapter describes the scale anchoring procedures that were applied to describe student performance at the international benchmarks for TIMSS Advanced 2015. The analysis was conducted separately for advanced mathematics and for physics. In brief, scale anchoring involved identifying items that students scoring at the international benchmarks answered correctly, and then having experts examine the content of each item to determine the kind of knowledge, skill, or reasoning demonstrated by students who responded correctly to the item. The experts then summarized the detailed list of item competencies in a brief description of achievement at each international benchmark. Thus, the scale anchoring procedure yielded a content-referenced interpretation of the achievement results that can be considered in light of the TIMSS Advanced 2015 frameworks for assessing advanced mathematics and physics.

Classifying the Items

As the first step, students scoring within 40 scale-score points of each benchmark (i.e., the benchmark plus or minus 20) were identified for the benchmark analysis. The range of 40 points provided an adequate sample of students scoring at the benchmark, yet was small enough so that performance at one international benchmark was still distinguishable from the next. The score ranges around each international benchmark and the number of students scoring in each range are shown in Exhibit 14.1.

Exhibit 14.1: Range Around Each International Benchmark and Number of Students Within Each Range

	Intermediate (475)	High (550)	Advanced (625)
Range of Scale Scores	*455–495*	*530–570*	*605–645*
TIMSS Advanced Advanced Mathematics	5,887	4,369	1,687
TIMSS Advanced Physics	3,083	2,318	1,071

The second step involved computing the percentage of those students scoring in the range around each international benchmark that answered each item correctly. To compute these percentages, students in each country were weighted proportionally to the size of the student population in the country. For multiple-choice items and constructed response items worth 1 point, it was a straightforward matter of computing the percentage of students at each benchmark who answered each item correctly. For constructed response items scored for partial and full credit, percentages were computed for students receiving partial credit (1-point) as well as for students receiving full credit (2-points).

Third, the criteria described below were applied to identify the items that anchored at each benchmark. An important feature of the scale anchoring method is that it yields descriptions of the performance demonstrated by students reaching each of the international benchmarks on the scales, and that the descriptions reflect demonstrably different accomplishments by students reaching each successively higher benchmark. Because the process entails the delineation of sets of items that students at each international benchmark are likely to answer correctly and that discriminate between one benchmark and the next, the criteria for identifying the items that anchor considers performance at more than one benchmark.

For multiple-choice items, 65 percent was used as the criterion for anchoring at each benchmark being analyzed, since students would be likely (about two thirds of the time) to answer the item correctly. A somewhat less strict criterion was used for the constructed response items, because students had much less scope for guessing. For constructed response items, the criterion of 50 percent was used for the benchmark without any discrimination criterion for the next lower benchmark. In addition, a criterion of less than 50 percent was used for the next lower benchmark, because with this response probability, students were more likely to have answered the item incorrectly than correctly.

Using a multiple-choice item as an example, the criteria for each benchmark are outlined below:

- A multiple-choice item anchored at the Intermediate International Benchmark (475) if at least 65 percent of students scoring in the range answered the item correctly. Because this was the lowest benchmark described, there were no further criteria.
- A multiple-choice item anchored at the High International Benchmark (550) if at least 65 percent of students scoring in the range answered the item correctly, and less than 50 percent of students at the Intermediate International Benchmark answered the item correctly.
- A multiple-choice item anchored at the Advanced International Benchmark (625) if at least 65 percent of students scoring in the range answered the item correctly, and less than 50 percent of students at the High International Benchmark answered the item correctly.

To include all of the multiple-choice items in the anchoring process and provide information about content domains and cognitive processes that might not otherwise have had many anchor items, the concept of items that "almost anchored" was introduced. These were items that met slightly less stringent criteria for being answered correctly. The criteria to identify multiple-choice items that "almost anchored" were that 60 to 65 percent of students scoring in the range answered the item correctly and less than 50 percent of students at the next lowest benchmark answered the item correctly. To be completely inclusive for all items, items that met only the criterion that

60 to 65 percent of the students answered correctly (regardless of the performance of students at the next lower point) were also identified. The categories of items were mutually exclusive, and ensured that all of the items were available to inform the descriptions of student achievement at the anchor levels. A multiple-choice item was considered to be "too difficult" to anchor if less than 60 percent of students at the advanced benchmark answered the item correctly. A constructed response item was considered to be "too difficult" to anchor if less than 50 percent of students at the advanced benchmark answered the item correctly.

Exhibit 14.2 presents the number of TIMSS Advanced 2015 advanced mathematics and physics items that anchored at each international benchmark. A description of the items for advanced mathematics and physics can be found in Appendix 14A and 14B, respectively. It should be noted that a partial credit item can anchor twice, typically at a higher benchmark for full credit, and a lower benchmark for partial credit (but sometimes both anchored at the same level). Scale anchoring for the physics items considered partial credit and full credit responses separately. Scale anchoring for advanced mathematics used only the full credit anchoring results.

Exhibit 14.2: Number of Items Anchoring and Almost Anchoring at Each International Benchmark

	Intermediate (475)	High (550)	Advanced (625)	Above Advanced	Total
TIMSS Advanced – Advanced Mathematics					
Algebra	6	20	11	0	37
Calculus	5	12	13	4	34
Geometry	6	9	12	3	30
Advanced Mathematics Total	**17**	**41**	**36**	**7**	**101**
TIMSS Advanced – Physics					
Mechanics & Thermodynamics	12	19	7	8	46
Electricity & Magnetism	10	6	9	6	31
Wave Phenomena & Atomic/Nuclear Physics	14	8	11	5	38
Physics Total	**36**	**33**	**27**	**19**	**115**

Writing the Scale Anchoring Descriptions

The scale anchoring for TIMSS Advanced 2015 was conducted in the spring of 2016 at a four-day meeting in Seoul, South Korea. In preparation for review by SMIRC, staff at the TIMSS & PIRLS International Study Center used examples from previous assessments to draft short descriptions of the student competencies demonstrated by a correct (or partially correct) response to each advanced mathematics and physics item. Then, the advanced mathematics and physics items were separately grouped by international benchmark, and within each benchmark the items were sorted by content area. The final categorization was by the anchoring criteria the items met—items that anchored, followed by items that almost anchored, followed by items that met only the 60 to 65 percent criteria. Also, in addition to the short draft descriptions, the following information was included for each item: framework classification, answer key or scoring guide, secure status, percent correct at each benchmark, and overall international percent correct.

At the scale anchoring meetings, the expert committees 1) worked through each item to finalize the description of the student competencies demonstrated by a correct (or a partially correct) response, 2) summarized the proficiency demonstrated by students reaching each international benchmark for publication in reports, and 3) selected example items that supported and illustrated the benchmark descriptions to publish together with the descriptions.

Following the scale anchoring meeting, the descriptions and example items published in the TIMSS Advanced 2015 report were reviewed by National Research Coordinators at their 8th meeting in Quebec City, Canada.

Appendix 14A: TIMSS Advanced 2015 Advanced Mathematics Item Descriptions Developed During the TIMSS Advanced 2015 Benchmarking

Items at Intermediate International Benchmark (475)	
Algebra	
M2_01	Recognizes the graph of the absolute value of a function given the graph of the function
M3_01	Determines which term has a given value in a geometric sequence
M3_04	Analyzes steps in a given solution of a simple logarithmic equation and identifies an error
M7_02	Computes the value of a composite function at a given value
M8_01	Identifies the expression that results from the composite of a function with itself
M9_02	Evaluates an exponential expression with three unknowns given three possible values for each unknown
Calculus	
M1_05	Differentiates an exponential function where the exponent is a simple polynomial
M3_06	Analyzes the graph of a function to determine the sign of its derivative
M4_05	Computes the limit of an exponential function
M6_05	Integrates the sum of an exponential function and a monomial
M8_05	Determines the limit of a rational function in terms of an unknown constant
Geometry	
M1_08	Calculates the difference between vectors in coordinate form
M2_11	Finds the length of a diagonal of a regular hexagon of given side length
M3_09	Evaluates the shortest path between opposite vertices on the surface of a cube
M3_10	Solves a word problem about height given the distance and angle of elevation
M6_09	Recognizes a diagram of the sum of three vectors
M9_09	Identifies the length of a side of an isosceles triangle using properties of a similar triangle

Items at High International Benchmark (550)	
Algebra	
M1_01	Rationalizes the denominator of an expression
M1_03	Determines when a rational function with numerator and denominator in factored form is negative
M2_02	Indicates whether factored polynomials satisfy two given conditions (2 of 2 points)
M2_05	Determines the values of two constants in a rational expression given its graph with two specified points
M3_02	Solves a word problem about the number of permutations
M3_03	Solves a word problem involving dimensions of two cylindrical containers given their volumes (2 of 2 points)
M4_01	Simplifies an expression with log base 10 in the exponent
M4_04	Determines the values of two constants in a rational function given its asymptotes
M5_02	Identifies two constants in a rational function given two points on its graph
M5_05A	Solves a word problem by finding the distance between the points at which a parabola intersects the x-axis
M6_01	Recognizes the graph that could represent a function and its inverse
M6_02	Identifies the solution of a quadratic inequality
M6_03	Solves an exponential decay equation for the time at which a specified amount of substance remains
M7_01	Determines the interval on which a given rational function is greater than the square of that function
M7_03	Multiplies complex numbers
M7_04	Determines the domain of a logarithm of a rational function
M8_02	Finds the value of a particular term of an arithmetic sequence
M8_03	Uses the initial value of a fractional expression with three unknowns to evaluate the expression after the unknowns are divided by multiples of 2
M9_01	Identifies an increasing function defined for all real numbers
M9_04	Determines the value of an unknown in a logarithmic equation given its two solutions
Calculus	
M2_07	Identifies the graph of a function that satisfies given conditions for the first and second derivatives
M2_08	Determines the limit of a rational function in terms of an unknown constant

M3_05	Finds the second derivative of a rational function (2 of 2 points)
M4_06	Identifies the derivative of a composite trigonometric function
M4_07	Identifies the graph of a function given the graph of its first derivative
M4_08	Identifies the values of a definite integral with an unknown upper bound
M6_07	Identifies the local maximum of a function given intervals on which its first and second derivatives are positive, negative, and zero
M6_08	Sketches the graph of a function on a specified interval with three given properties (2 of 2 points)
M7_05	Uses the additivity of intervals to identify the value of a definite integral
M7_06	Determines the derivative of the product of a monomial and an unspecified function
M9_05	Identifies a true statement about discontinuity and non-differentiability for a graph of a piecewise function
M9_06	Recognizes the graph of the derivative of a curvilinear, discontinuous function
Geometry	
M2_10	Determines the value of a trigonometric function given the value of a related function
M4_09	Determines the ratio of the squares of two sides of a scalene triangle given two of its angles
M4_10	Finds the maximum value of a trigonometric function and a value of the independent variable at which it occurs (2 of 2 points)
M4_11	Proves that a quadrilateral with given coordinates of its vertices is a parallelogram
M5_08	Identifies coordinates of the fourth vertex of a parallelogram when three vertices are given
M7_10	Recognizes the description of a sine graph transformation
M8_09	Identifies a vector that is perpendicular to a given vector in a coordinate system
M8_10	Determines the lengths of two sides of a triangle given its area, the sum of the lengths of the two sides, and the angle included between them
M9_10	Determines the coordinates of line segment endpoints given the midpoint

Items at Advanced Benchmark (625)	
Algebra	
M1_02	Calculates the cube of a complex number given in trigonometric form
M2_03	Finds the sum of the first 100 terms of an alternating series at a given value of x
M2_04	Determines the sum of an infinite alternating geometric series

M4_02	Determines the intersection of two functions in terms of an unknown, non-zero coefficient (2 of 2 points)
M4_03	Determines the value when one cost becomes less than another and explains whether increasing the initial costs will change the value (2 of 2 points)
M5_01	Given the first three terms, calculates the sum of an infinite geometric series
M5_03	Solves a logarithmic equation (2 of 2 points)
M5_04	Given one imaginary root, identifies the constant term of a third-degree polynomial with known coefficients
M6_04	Determines the coefficient of the linear term and the constant of a quadratic equation given its solution
M8_04	Determines the amount of time that a ball is at or above a specified height given the quadratic function for its height (2 of 2 points)
M9_03	Determines the values of an unknown coefficient for which the graph of a parabola lies above the x-axis
Calculus	
M1_06	Maximizes the volume of a cylinder given a relationship between its height and diameter
M2_06	Identifies the value of a definite integral from areas shown on a graph
M2_09	Explains whether a given piecewise function is continuous at a given value
M3_08	Calculates the area between the graphs of a linear and a quadratic function (2 of 2 points)
M5_06	Given the graph of the derivative of a function, determines the x-values of the maximum point and the point of inflection of the function (2 of 2 points)
M6_06	Explains whether a right-hand limit and a left-hand limit of a function are equal
M7_07	Maximizes the area of a rectangle with constraint on the sum of three sides and explains why the solution gives the maximum area (2 of 2 points)
M7_08	Identifies specific properties of the first and second derivatives of a function given its graph
M7_09	Determines the limit of a rational function in terms of an unknown constant
M8_06	Indicates whether statements about the continuity or differentiability of a function with given conditions are true (2 of 2 points)
M8_07	Solves a multi-step word problem by maximizing the profit given a quadratic cost function and the linear income function (2 of 2 points)
M9_08	Determines the equation of a line parallel to a tangent line of a given function at a specified point (2 of 2 points)
M9_08	Indicates whether statements about a function are true given a graph of the derivative (2 of 2 points)

Geometry	
M1_07	Identifies the equation of a line through a given point and perpendicular to a given line
M1_10	Uses vector sums and differences to express a relationship among three vectors shown in a figure
M2_12	Determines the length of a line segment in a problem involving similar right triangles
M3_11	Uses properties of vectors to analyze equivalence of conditions involving the sum and difference of two vectors
M5_09	Compares amplitudes and periods of sine functions
M6_10	Justifies a statement regarding the length of the radius of a circle drawn on a square grid (2 of 2 points)
M6_11	Identifies the parameter of a sine function given the graphs of a function and its transformation
M7_11	Solves a word problem involving concentric circles and areas of sectors (2 of 2 points)
M7_12	Explains why the sum of a sine and a cosine function does not exceed a specified value
M8_11	Determines a diagonal length of a rhombus in terms of the length of a side given the ratio between the obtuse and acute angles
M9_11	Identifies the parameters of a cosine function used to model data presented in a graph
M9_12	Proves that a trigonometric relation holds for a triangle with specified angle and side measures

Items Above the Advanced International Benchmark (625)	
Calculus	
M3_07	Solves a multi-step word problem by maximizing the profit given a quadratic cost function and the unit selling price
M5_05B	Solves a multi-step word problem by calculating the area between two intersecting parabolas
M5_07	Determines the vertical line that divides a specified area between a parabola and the x-axis into equal parts
M8_08	Shows a process for integrating the product of a linear and a trigonometric function
Geometry	
M1_09	Given two points, identifies an equation that represents the set of all points twice as far from one of the given points as from the other
M5_10	Calculates the two possible lengths of a side of a triangle given an angle and the lengths of two sides that do not include the angle (2 of 2 points)
M6_12	Proves the equality of sines of supplementary angles

Appendix 14B: TIMSS Advanced 2015 Physics Item Descriptions Developed During the TIMSS Advanced 2015 Benchmarking

Items at Intermediate International Benchmark (475)	
Mechanics & Thermodynamics	
P1_05	Recognizes the process of energy transfer from the Sun to the Earth
P2_01B	Compares the amount of time it takes an object to reach the apex of its motion from a given point and the time it takes to fall from the apex back to the given point
P3_01	Selects the graph that best represents the potential energy of a ball rolling up and down an inclined plane
P3_02	Describes the direction of the acceleration of a body moving in a circular path with constant speed
P3_08	Identifies the best explanation for the temperature change in a rising air mass
P4_02	Recognizes how the force exerted by the Sun on Planet X compares with the force exerted by the Sun on the Earth, given the masses of the planets and the relationship between their distances to the Sun
P4_03	Calculates the final velocity of two skiers after they collide inelastically (1 of 2 points)
P6_01	Recognizes the relationship between the change in internal energy and the change in temperature of a gas when work is done on it by the environment
P6_02	Calculates the initial height from which a body began moving vertically down (1 of 2 points)
P7_03	Identifies an energy transformation that occurs when a meteor enters Earth's atmosphere and is incinerated
P8_01B	Identifies the diagram that best represents the path of a ball attached to a string after it has been released from circular motion at a constant speed
P9_02	Calculates work done by friction to stop an object sliding along a rough surface
Electricity & Magnetism	
P2_05A	Identifies the direction of the force on a point charge in various positions in an electric field
P2_05B	Orders three points in an electric field by increasing field strength
P3_04	Identifies the direction of the electric force on a charged object in an electric field
P3_06	States the meaning of the symbols in a formula for a charged particle moving in a magnetic field
P6_06	Completes a diagram to indicate the direction of current induced in a coil that is moving towards a stationary current-carrying coil
P7_05B	Identifies the path of a negatively charged particle as it passes between two charged plates

P7_07	Identifies the best explanation for why a fluorescent tube lights up when it is positioned close to a charged balloon
P8_04	Recognizes the changes in magnitude of the magnetic flux through a conducting coil as a magnet enters, moves inside, and leaves the coil
P8_06	Evaluates descriptions of the resistance in an unknown electrical component based on its current-voltage graph
P9_06	Evaluates descriptions of processes by which a flashlight containing a coil of wire and a magnet that can slide through the coil produces light
Wave Phenomena & Atomic/Nuclear Physics	
P1_01	Recognizes a correct statement about black lines in the continuous spectrum of sunlight
P1_07	Evaluates reasons for the difference between the input and output energies associated with the photoelectric effect
P2_08	Calculates the wavelength of a sound wave above water
P2_09A	Evaluates descriptions of the result of increasing the temperature of a black body on the radiation it emits
P3_10	Completes a table to indicate the number of protons and neutrons in given isotopes
P4_10	States what happens to the wavelengths of water waves that decrease in speed as they approach the shore
P5_01	Recognizes a range of wavelengths associated with visible light
P6_09	Evaluates experimental set-ups to compare the effect of changing the apex angle of a prism on the angle between incident and refracted rays of light and chooses the best pair
P6_10	Calculates the wavelength of a musical note
P6_11	Recognizes the best explanation for why electromagnetic radiation is characterized by photon energy, radiation frequency, and radiation wavelength
P7_08A	Calculates the speed of a wave moving down an oscillating rope
P8_08	Determines the wavelength of a wave presented as a graphical trace
P8_10	Determines the atomic numbers and mass numbers of 2 isotopes involved in nuclear reactions (1 of 2 points)
P9_08	Evaluates possible factors that account for the differences in interference patterns produced by two different subatomic particles with equal kinetic energies

Items at High International Benchmark (550)

Mechanics & Thermodynamics	
P1_04	Derives an expression for the speed at the top of the trajectory of an object moving in a vertical circular path
P2_01A	Recognizes the acceleration at the apex of an object thrown vertically upward

P2_04	Shows the steps in a calculation of the amount of energy required to increase the temperature of water in a given context
P3_03	Recognizes the best explanation for a ball rebounding to a height that is less than the initial height of release
P3_07	Calculates the new volume of an ideal gas when pressure and temperature change (1 of 2 points)
P4_01	Identifies the ratio of the maximum temperature to the minimum temperature of a sample of a gas during a closed cycle represented in a volume-pressure graph
P4_03	Shows the steps in a calculation of the final velocity of two skiers after they collide inelastically (2 of 2 points)
P4_04	Identifies the direction two balls will travel after they collide inelastically
P5_07	Calculates the energy released when a container of water cools
P6_02	Shows the steps in a calculation of the initial height from which a body began moving vertically down (2 of 2 points)
P6_04	Recognizes the equation describing the force of friction acting on an object sliding down an inclined plane
P6_05	Recognizes the information required to calculate the speed of a satellite in orbit around the Earth
P7_01	Identifies the best estimate for the coefficient of friction between an object and the surface along which it is being dragged
P7_02B	Identifies a reason that the height of a spacecraft above the surface of a planet varies during its orbit
P8_01A	Recognizes the diagram that best represents the direction of the net force acting on a ball attached to a string and moving in a circle at constant speed
P8_02	Describes one step in a sequence for checking the calibration of a thermometer, given a list of available equipment (1 of 2 points)
P8_03A	Calculates the magnitude of the normal force on a body sliding on the inside of a smooth cylindrical surface at a specified angle
P9_03	Identifies the best estimate for the acceleration of an elevator
P9_04	Calculates the temperature of a gas after compression (1 of 2 points)
Electricity & Magnetism	
P2_06	Evaluates explanations for the increase in temperature of an iron plate positioned near a coil of wire connected to an alternating voltage source
P3_05	Ranks the equivalent resistance for four different combinations of resistors
P5_03	Calculates the resistance in a flashlight bulb using Ohm's Law and Joule's law
P5_04	Recognizes paths of a neutral particle and a positively charged particle in a magnetic field shown in a diagram
P6_08	Completes a diagram to indicate the direction of net force on a point charge influenced by two other point charges
P9_05A	Calculates the magnitude of the magnetic field acting on a proton (1 of 2 points)

Wave Phenomena & Atomic/Nuclear Physics	
P2_07	Recognizes the source of energy used to generate electricity in a nuclear power plant
P4_08B	Compares two types of electromagnetic radiation and explains which type is more harmful to humans in terms of the frequency and energy of the photons, given a diagram of the electromagnetic spectrum
P4_09	Recognizes what accounts for the difference in the mass of an atom before and after a nuclear reaction
P4_11	Explains which semiconductor is appropriate to use in a solar panel, given a graph of the performance of each semiconductor across a range of wavelengths of light
P5_11	Identifies an estimate of the age of an organic specimen, given the concentration of carbon-14 in it
P7_08B	Identifies the relationship between the initial and final frequencies and wavelengths of a wave with a final speed less than its initial speed
P8_07	Identifies the index of refraction of a piece of glass, given a diagram showing the glass, the angle of incidence, and angle of refraction
P8_09	Orders examples of electromagnetic radiation in terms of increasing photon energies

Items at Advanced International Benchmark (625)

Mechanics & Thermodynamics	
P2_02	Evaluates a mechanical system run by an electric motor and predicts the difference between the theoretical and actual final temperatures of the system
P5_05	Deduces the tension in the string connecting two unequal masses in freefall
P5_08	Identifies the temperature at which two rods of different metals will have the same length
P7_02A	Calculates an estimate of the mass of a planet given information about the speed of a spacecraft in orbit around it and the radius of the orbit (1 of 2 points)
P8_02	Describes a sequence of steps for checking the calibration of a thermometer, given a list of available equipment (2 of 2 points)
P8_03B	Calculates the speed of a body at the lowest point of its trajectory (1 of 2 points)
P9_04	Shows the steps in a calculation for the temperature of a gas after compression (2 of 2 points)
Electricity & Magnetism	
P1_08	Analyzes a complex circuit diagram to determine the power consumption of light bulbs
P4_06	Identifies the distance at which an electric field is four times less than it is at a given distance from the source
P4_07	Identifies the prediction for the change in the path of a horizontal electron beam as a result of the presence of a magnetic field
P5_02	Interprets a current vs. resistance graph to identify the internal resistance of a battery

P7_05A	Calculates the electric force on a negatively charged particle when it is in between two charged plates (1 of 2 points)
P7_05A	Shows the steps in a calculation of the electric force on a negatively charged particle when it is in between two charged plates (2 of 2 points)
P8_05	Identifies the diagram of an electromagnet that depicts the direction of the current and the polarity, given the orientation of the battery
P9_05A	Shows the steps in a calculation of the magnitude of the magnetic field acting on a proton (2 of 2 points)
P9_05B	Identifies the direction of the magnetic field acting on a proton
Wave Phenomena & Atomic/Nuclear Physics	
P3_11	Completes the equation for a nuclear fission reaction
P4_08A	Recognizes the type of radiation associated with a given range of wavelengths in the electromagnetic spectrum
P5_09	States that a red object absorbs light of all wavelengths from a green light source (1 of 2 points)
P5_10	Justifies an argument that it might be more appropriate to indicate that an object is hot by associating it with the color blue
P6_12	Explains which of two heated bars is hotter in terms of the relationship between the color of emitted light and temperature
P7_04	Recognizes a correct statement about an oscillating electric field in a transmitting antenna generating a magnetic field
P8_10	Determines the atomic numbers and mass numbers of 3 isotopes involved in nuclear reactions (2 of 2 points)
P9_07	Recognizes whether the frequency and wavelength of light change as the light passes from air to water
P9_09A	Explains which pair of atomic reactants can most likely be used in a fusion reaction to produce usable energy for humans, given a temperature-reaction rate graph
P9_09B	Recognizes the information needed to calculate the energy production of three pairs of atomic reactants in a fusion reaction
P9_09C	Calculates the mass lost in a fusion reaction (1 of 2 points)

Items Above the Advanced International Benchmark (625)

Mechanics & Thermodynamics	
P1_02	Identifies the force recorded on one of two spring balances, given the force recorded on the other spring balance and the relationship between the two spring constants
P2_03	Recognizes the path of motion of the center of mass of a curved bar as it flies through the air
P3_07	Shows the steps in a calculation of the new volume of an ideal gas when pressure and temperature change (2 of 2 points)
P3_09	Interprets the context of a solar cooker and states that food in the cooker comes to equilibrium with its surroundings (1 of 2 points)

P3_09	Interprets the context of a solar cooker to explain why, when the cooker is placed in the sun, food heats steadily and then stays at a constant temperature (2 of 2 points)
P6_03	Identifies the relationship between two forces exerted on an object at the apex of its curved motion
P7_02A	Shows the steps in a calculation for an estimate of the mass of a planet given information about the speed of a spacecraft in orbit around it and the radius of the orbit (2 of 2 points)
P8_03B	Shows the steps in a calculation for the speed of a body at the lowest point of its trajectory (2 of 2 points)
Electricity & Magnetism	
P1_06	Identifies the direction of the force on a current-carrying conductor in a given magnetic field
P4_05	Explains how a charged balloon sticks to a wall
P6_07	Predicts the direction of movement of a foil strip as a permanent magnet approaches it (1 of 2 points)
P6_07	Predicts the direction of movement of a foil strip as a permanent magnet approaches it and explains the prediction (2 of 2 points)
P7_06A	Identifies an explanation for the change in polarity of the induced emf as a magnet passes through a coil of conducting wire
P7_06B	Explains the difference in magnitude of the induced emf at its extrema as a magnet passes through a coil of conducting wire
Wave Phenomena & Atomic/Nuclear Physics	
P1_03	Identifies the component of Rutherford's experimental set-up that should be varied to obtain the appropriate data
P1_09	Identifies the effect of a nuclear reaction on the atomic and mass numbers of an atom
P2_09B	Evaluates the conclusion that Wien's Law holds for an object, based on three observations of temperature and wavelength of emitted radiation
P5_09	States that a red object absorbs light of all wavelengths from a green light source and explains the observation (2 of 2 points)
P9_09C	Shows the steps in a calculation of the mass lost in a fusion reaction (2 of 2 points)