Chapter 9

Physics Performance at the TIMSS Advanced 2008 International Benchmarks

As was described more fully in the Introduction, the TIMSS Advanced 2008 physics achievement scale summarizes students' performance on test items designed to measure breadth of content in mechanics, electricity and magnetism, heat and temperature, and atomic and nuclear physics, as well as a range of cognitive processes within the knowing, applying, and reasoning domains. To interpret the achievement results in meaningful ways, it is important to understand the relationship between scores on the scale and students' success on the content of the assessment. As a way of interpreting the scaled results, three points on the scale were identified as international benchmarks and descriptions of student achievement at those benchmarks in relation to students' performance on the test items were developed. The TIMSS Advanced benchmarks represent the range of performance shown by students internationally. The Advanced International Benchmark is 625, the High International Benchmark is 550, and the Intermediate International Benchmark is 475. In TIMSS at the fourth and eighth grade levels, four benchmarks were used: viz., advanced, high, intermediate, and low. The Low International Benchmark was not included in the TIMSS Advanced benchmarking analysis since, in all the participating countries, this is a highly select population of students.

The TIMSS & PIRLS International Study Center worked with a committee of experts[1] from several countries to conduct a detailed scale anchoring analysis to describe physics achievement at these benchmarks. Scale anchoring is a way of describing TIMSS Advanced 2008 performance at different points on the TIMSS Advanced physics scale in terms of the types of items students answered correctly. In addition to a data analysis component to identify items that discriminated between successive points on the scale,[2] the analysis also involved a judgmental component in which committee members examined the physics content and cognitive processing dimensions assessed by each item and generalized to describe students' knowledge and understandings.

This chapter presents the TIMSS Advanced 2008 physics achievement results at the international benchmarks for the participating countries. Then, benchmark by benchmark, there is a description of the understanding of physics content and types of cognitive processing skills and strategies demonstrated by students at each of the international benchmarks, together with illustrative items. For each example item, the percent correct for each of the TIMSS Advanced 2008 participants is shown. For multiple-choice items, the correct answer is identified by a bullet, •, and the percent of students in each country who chose each response is also given. For constructed-response items, a copy of the scoring guide showing the percent of students choosing each correct or incorrect approach to the solution is provided, along with a student response that was given full credit.[3] The items published in this report were selected from the items released for public use.[4] Every effort was made to include examples which not only illustrated the particular benchmark under discussion, but also represented different item formats and content area domains.

1 In addition to Robert A. Garden, the TIMSS Advanced Mathematics Coordinator, and Svein Lie, the TIMSS Physics Coordinator, committee members included Carl Angell, Wolfgang Dietrich, Liv Sissel Gronmo, Torgeir Onstad, and David F. Robitaille.

2 For example, in brief, a multiple-choice item anchored at the Advanced International Benchmark if at least 65 percent of students scoring at 625 answered the item correctly and fewer than 50 percent of students scoring at the High International Benchmark (550) answered correctly, and so on, for each successively lower benchmark. Since constructed-response questions nearly eliminate guessing, the criterion for the constructed-response items was simply 50 percent at the particular benchmark. For more information, see the *TIMSS Advanced 2008 Technical Report*.

3 All of the constructed-response items were scored according to detailed scoring guides containing descriptions and examples of the types of responses that should receive credit. Although most constructed-response items were worth 1 point, some were worth 2 points (with 1 point awarded for partial credit). If the example item was worth 2 points, the data are for responses receiving 2 points (full credit).

4 After each TIMSS assessment, a certain proportion of the items are released into the public domain and the rest of the items are kept secure for use in measuring trends over time in subsequent assessments. In the case of TIMSS Advanced, more than one-half of the items are being released.

How Do Countries Compare on the TIMSS Advanced 2008 International Benchmarks of Physics Achievement?

Exhibit 9.1 summarizes what students of physics in the participating countries who score at the TIMSS international benchmarks typically know and can do in physics. The data show that there were substantial differences in students' performance across the three benchmarks. Students at the Advanced International Benchmark demonstrated their ability to combine and apply concepts and laws of physics in solving complex problems in a variety of situations. Students at the High International Benchmark were able to apply basic laws of physics in solving problems in a variety of situations. Those at the Intermediate International Benchmark demonstrated knowledge of the physics underlying a range of phenomena pertinent to everyday life.

Exhibit 9.2 displays the percent of physics students in each country who reached each of the three international benchmarks. The percents displayed in each row corresponding to the three international benchmarks are cumulative. Every student who scored at the Advanced Benchmark is also included in the High and Intermediate Benchmark categories.

For each country, Exhibit 9.2 shows the percent of physics students who reached each international benchmark as well as the TIMSS Advanced Physics Coverage Index for that country. In the table, the countries are listed in descending order of the percent of their students who reached the Advanced Benchmark. As might be expected, given that they had the highest physics achievement on average, the Netherlands and the Russian Federation had the highest percentages attaining the Advanced International Benchmark, 21 and 19 percent, respectively. A group including Slovenia, Norway, and Armenia followed in the 10 to 12 percent range. Much larger percentages of

Exhibit 9.1 TIMSS Advanced 2008 International Benchmarks of Physics Achievement

TIMSSAdvanced2008 Physics

Advanced International Benchmark – 625

Summary

Students can combine and apply concepts and laws of physics in solving complex problems in a variety of situations.

Students can combine conceptual understanding, reasoning, and calculation to solve problems. They can also select relevant information and interpret and use data from graphs and diagrams. Students can combine and apply concepts and laws of mechanics, including momentum, in complex problem situations. They can apply Ohm's law and Joule's law to complex circuits, and identify the direction of the force on a conductor in a magnetic field. They can determine the direction and the magnitude of a resulting electric force and field from an arrangement of charged particles. Students can solve problems by applying their knowledge of heat conduction. They can compare lengths using coefficients of linear expansion. They can apply the gas laws to solve straightforward problems. Students can apply knowledge of notation for isotopes and principles of conservation of charge and number of nucleons in solving problems about radioactive decay and nuclear reactions.

High International Benchmark – 550

Summary

Students can apply basic laws of physics in solving problems in a variety of situations.

Students can apply laws of mechanics, conservation of energy, and energy transformation to solve problems involving vertical circular motion, compression of springs, collisions, and tension in strings. They can apply Ohm's law and Joule's law to solve simple problems, and can identify properties of charged particle motion in electric and magnetic fields. Students can apply knowledge of the relative size of an atom and its nucleus, and solve problems involving the half-life of a radioactive isotope. They also can apply basic knowledge of heat capacity and relate different types of electromagnetic radiation to the temperature of a heat-emitting body, and demonstrate understanding of sound wave phenomena.

Intermediate International Benchmark – 475

Summary

Students demonstrate knowledge of the physics underlying a range of phenomena pertinent to everyday life.

Students can apply basic laws of mechanics to situations involving free-falling objects, circular motion, and wave motion. Students can apply knowledge about heat and temperature in a variety of contexts including heat transfer, the greenhouse effect, and the role of pressure in the relationship between altitude and temperature. They can relate different types of electromagnetic radiation to their wavelengths and read a simple circuit diagram. Students demonstrate knowledge of the components of an atomic nucleus and its notation and apply knowledge of the photoelectric effect.

Exhibit 9.2 **Percent of Students Reaching the TIMSS Advanced 2008 International Benchmarks of Physics Achievement**

TIMSSAdvanced2008 Physics

Country	Percent of Students Reaching the International Benchmarks: Advanced Benchmark (625)	High Benchmark (550)	Intermediate Benchmark (475)	TIMSS Advanced Physics Coverage Index
† Netherlands	21 (2.2)	73 (2.5)	98 (1.0)	3.4%
Russian Federation	19 (2.7)	42 (3.4)	66 (3.2)	2.6%
‡ Slovenia	12 (1.3)	44 (1.5)	77 (1.4)	7.5%
Norway	11 (1.4)	43 (2.2)	79 (1.7)	6.8%
Armenia	10 (1.5)	29 (2.4)	58 (2.7)	4.3%
Iran, Islamic Rep. of	9 (1.5)	23 (2.6)	43 (2.7)	6.6%
Sweden	7 (0.8)	30 (1.9)	62 (2.5)	11.0%
Italy	2 (0.7)	11 (1.7)	31 (3.0)	3.8%
Lebanon	0 (0.2)	8 (0.9)	36 (1.7)	5.9%

SOURCE: IEA TIMSS Advanced 2008 ©

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses.

Exhibit 9.3 **Trends in Percent of Students Reaching the TIMSS Advanced 2008 International Benchmarks of Physics Achievement**

TIMSSAdvanced2008 Physics

Country	TIMSS Advanced Physics Coverage Index 2008	TIMSS Advanced Physics Coverage Index 1995	Advanced International Benchmark (625): 2008 Percent of Students		Advanced International Benchmark (625): 1995 Percent of Students	High International Benchmark (550): 2008 Percent of Students		High International Benchmark (550): 1995 Percent of Students	Intermediate International Benchmark (475): 2008 Percent of Students		Intermediate International Benchmark (475): 1995 Percent of Students
Russian Federation	2.6%	1.5%	19 (2.7)		21 (2.9)	42 (3.4)		53 (4.9)	66 (3.2)	▼	77 (3.6)
‡ Slovenia	7.5%	38.6%	12 (1.3)		15 (4.7)	44 (1.5)		45 (6.8)	77 (1.4)		73 (4.8)
Norway	6.8%	8.4%	11 (1.4)	▼	28 (2.7)	43 (2.2)	▼	68 (3.7)	79 (1.7)	▼	93 (1.4)
Sweden	11.0%	16.3%	7 (0.8)	▼	25 (2.4)	30 (1.9)	▼	66 (2.8)	62 (2.5)	▼	92 (1.4)

SOURCE: IEA TIMSS Advanced 2008 ©

▲ 2008 percent significantly higher than 1995

▼ 2008 percent significantly lower than 1995

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses.

physics students in the Netherlands reached the High and Intermediate Benchmarks than in any other country: 73 and 98 percent, respectively. Norway was next with 43 and 79 percent, respectively. Fewer than half the physics students in Iran, Italy, and Lebanon reached the Intermediate Benchmark.

On the one hand, these students—the very best physics students in their respective countries—found the TIMSS Advanced physics test to be challenging. Only four countries had more than 10 percent of their students reaching the Advanced Benchmark, and no country exceeded 25 percent. On the other hand, in five of the nine countries, more than 50 percent reached at least the Intermediate Benchmark which, as shown in Exhibit 9.1, means that those students demonstrated knowledge of the physics underlying a range of phenomena pertinent to everyday life assessed by TIMSS Advanced 2008.

Exhibit 9.3 presents changes in the percent of students reaching the benchmarks between 1995 and 2008 for the four countries that participated in both studies. Countries are ranked in descending order of the percent of students who reached the Advanced International Benchmark in 2008. The display also shows the TIMSS Advanced Physics Coverage Index for each country in the 1995 and 2008 assessments. Slovenia had the most dramatic drop in its Coverage Index: from about 40 percent coverage in 1995 to about 8 percent in 2008. Norway and Sweden also reported decreases in coverage, and the Russian Federation was the only one to record an increase.

In Norway and Sweden, the percentages of students reaching each of the three benchmarks declined between 1995 and 2008. There was also a decline in the Russian Federation at the Intermediate Benchmark. Only Slovenia had no changes over this period in the percentages reaching international benchmarks.

Physics: Achievement at the Advanced International Benchmark

The TIMSS Advanced 2008 Assessment Frameworks called for the items to be included in the physics assessment to be divided across the four content domains as follows: 30 percent for mechanics, 30 percent for electricity and magnetism, 20 percent for heat and temperature, and 20 percent for atomic and nuclear physics.

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

The content of the electricity and magnetism domain deals with topics that 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. 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.

Although heat and temperature are distinct concepts, they are grouped into a single domain in the assessment framework. Heat is energy and, as such, can be transferred by many mechanisms, where temperature may be regarded as a measure of kinetic energy for molecules. Heat transfer from the Sun and between bodies of water, land masses, and the 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 wavelength of heat radiation is strongly dependent on the temperature of the radiating body.

The domain of atomic and nuclear physics covers much of what is sometimes referred to as modern physics, since the relevant theories and experiments have been published within the past 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.

In the mechanics domain, the framework specifies that students should be able to interpret a graph and apply the definition of momentum to solve a problem. Exhibit 9.4 shows a mechanics item in multiple-choice format that was likely to be solved correctly by students performing at the Advanced Benchmark. In the table accompanying this item, and in the corresponding table for the other example items, the countries are listed in descending order of their percent correct.

In this example (Example Item 1), students had to read information from a graph as well as from the stem of the item, and then use that information to find the momentum of a cyclist crossing the finish line in a race. The correct response, 800 kg•m/s, is bulleted in the exhibit. According to the information provided in Chapter 7 on the topics included in the intended curriculum and taught to the students (Exhibit 7.13), all countries included this topic in their curricula and virtually all students were taught it. Performance on this item in the Netherlands, Norway, and Slovenia was much higher than in the other countries, ranging from 74 to 78 percent correct. Students in Iran and Armenia found this item very difficult, with 33 and 26 percent responding correctly, respectively.

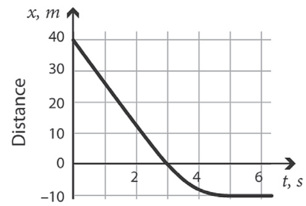
To obtain the correct answer, students had to calculate the speed of the cyclist as she crossed the finish line (40m/3s), and multiply that

Exhibit 9.4 **TIMSS Advanced 2008 Advanced International Benchmark (625) of Physics Achievement – Example Item 1**

TIMSSAdvanced2008 Physics

Content Domain: Mechanics

Description: Interprets a graph and applies the definition of momentum to solve a problem



The graph shown above represents a cyclist approaching and passing the finishing line in a race. If the cyclist weighs 60 kg, what is her momentum as she crosses the finishing line?

- Ⓐ 2400 kg · m/s
- ● 800 kg · m/s
- Ⓒ 600 kg · m/s
- Ⓓ 0 kg · m/s

Country	Percent Correct
† Netherlands	78 (2.4)
Norway	75 (2.1)
‡ Slovenia	74 (3.0)
Sweden	62 (2.5)
Russian Federation	52 (3.2)
Italy	46 (3.6)
Lebanon	43 (2.7)
Iran, Islamic Rep. of	33 (2.3)
Armenia	26 (3.4)

Country	Percent of Students				
	A	B Correct Response	C	D	NR*
† Netherlands	4 (1.0)	78 (2.4)	9 (1.5)	8 (1.5)	2 (0.9)
Norway	6 (1.0)	75 (2.1)	11 (1.5)	6 (1.4)	2 (0.8)
‡ Slovenia	7 (1.9)	74 (3.0)	11 (1.8)	7 (1.6)	2 (0.8)
Sweden	9 (1.4)	62 (2.5)	22 (2.2)	6 (1.0)	2 (0.7)
Russian Federation	9 (1.4)	52 (3.2)	21 (2.4)	15 (2.0)	3 (0.6)
Italy	12 (2.5)	46 (3.6)	12 (1.7)	10 (2.2)	20 (2.8)
Lebanon	9 (1.6)	43 (2.7)	19 (1.9)	24 (2.4)	4 (1.3)
Iran, Islamic Rep. of	9 (1.5)	33 (2.3)	19 (1.8)	20 (2.0)	18 (1.7)
Armenia	16 (2.9)	26 (3.4)	38 (4.2)	12 (2.4)	7 (1.9)

* No Response

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

number by the mass of the cyclist. Alternative C (600 kg•m/s) attracted more students than either of the others. Non-response rates were quite low except in the Islamic Republic of Iran (18%) and Italy (20%).

Exhibit 9.5 shows an example of a multiple-choice item from the electricity and magnetism domain that anchored at the Advanced Benchmark (Example Item 2). The item was designed to test students' ability to recognize the mutual electric forces acting on two charged particles. As in the case of Example Item 1, this material was included in both the intended and the implemented physics curriculum in every country. The item was very difficult, with 36 percent correct in Armenia being the best performance. The percent correct in the majority of countries was less than chance level (25%).

Non-response rates for this item were very low, which could mean that students everywhere seemed to think they knew what had to be done to obtain the correct response. In several countries, more students chose A as their answer choice than the correct answer, which may indicate that they recognized that the 2 charges would repel one another, but mistakenly thought that the magnitude of the forces on each charge were different. The second most popular incorrect answer choice was C.

The third example of an item that anchored at the Advanced Benchmark comes from the heat and temperature domain and is shown in Exhibit 9.6. Example Item 3 required students to apply their knowledge of heat conduction in different materials in solving a multiple-choice item. Performance on this item had the least cross-country variability of any of the example items, ranging from 64 percent correct in the Netherlands to 40 percent in the Russian Federation, Lebanon, and Italy.

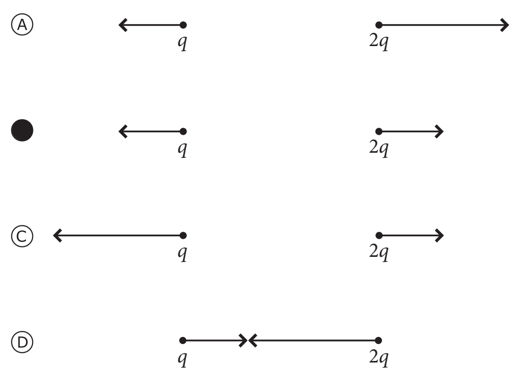
Exhibit 9.5 **TIMSS Advanced 2008 Advanced International Benchmark (625) of Physics Achievement – Example Item 2**

TIMSSAdvanced 2008 Physics

Content Domain: Electricity and Magnetism

Description: Identifies mutual electric forces acting on two charged particles

Two particles have charges q and $2q$, respectively. Which figure BEST describes the electric forces acting on the two particles?



Country	Percent Correct
Armenia	36 (4.1)
Sweden	30 (3.5)
Iran, Islamic Rep. of	29 (2.6)
Russian Federation	26 (2.8)
‡ Slovenia	20 (2.4)
Norway	17 (2.0)
† Netherlands	16 (1.9)
Italy	16 (2.8)
Lebanon	10 (1.8)

Country	Percent of Students				
	A	B Correct Response	C	D	NR*
Armenia	36 (4.6)	36 (4.1)	9 (2.0)	18 (2.4)	1 (0.4)
Sweden	38 (2.7)	30 (3.5)	25 (2.5)	5 (1.0)	1 (0.7)
Iran, Islamic Rep. of	26 (2.4)	29 (2.6)	32 (2.1)	12 (1.4)	1 (0.4)
Russian Federation	39 (2.9)	26 (2.8)	23 (2.3)	11 (1.8)	0 (0.2)
‡ Slovenia	38 (3.4)	20 (2.4)	30 (2.7)	12 (2.1)	1 (0.6)
Norway	48 (2.8)	17 (2.0)	26 (2.1)	8 (1.4)	0 (0.3)
† Netherlands	47 (2.7)	16 (1.9)	32 (2.7)	4 (1.0)	1 (0.4)
Italy	51 (4.3)	16 (2.8)	24 (2.9)	6 (1.4)	3 (1.1)
Lebanon	45 (2.7)	10 (1.8)	28 (2.5)	16 (1.9)	1 (0.6)

* No Response

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Exhibit 9.6 **TIMSS Advanced 2008 Advanced International Benchmark (625) of Physics Achievement – Example Item 3**

TIMSSAdvanced 2008 Physics

Content Domain: Heat and Temperature

Description: Applies knowledge of heat conduction in different materials

A table with metal legs and a wooden top is inside a room with a temperature of about 20 °C. Which statement explains why the metal legs feel colder than the wooden top?

Ⓐ The heat capacity of the metal legs is lower than the wooden top.

Ⓑ The metal has a lower temperature than the wooden top.

● The metal conducts heat better than wood.

Ⓓ The molecules move faster in metal than in wood.

Country	Percent Correct
† Netherlands	64 (2.6)
Armenia	60 (3.6)
‡ Slovenia	54 (3.6)
Iran, Islamic Rep. of	52 (2.5)
Sweden	52 (2.3)
Norway	42 (2.0)
Russian Federation	40 (3.0)
Lebanon	40 (2.3)
Italy	40 (3.0)

Country	Percent of Students				
	A	B	C Correct Response	D	NR*
† Netherlands	29 (2.7)	6 (1.4)	64 (2.6)	1 (0.4)	0 (0.0)
Armenia	13 (2.7)	17 (3.2)	60 (3.6)	9 (2.0)	1 (0.6)
‡ Slovenia	32 (3.3)	10 (1.9)	54 (3.6)	2 (0.9)	1 (0.7)
Iran, Islamic Rep. of	28 (2.0)	7 (1.3)	52 (2.5)	12 (1.6)	1 (0.4)
Sweden	37 (2.2)	5 (1.1)	52 (2.3)	6 (1.3)	0 (0.0)
Norway	45 (2.2)	6 (1.2)	42 (2.0)	7 (1.3)	1 (0.4)
Russian Federation	47 (2.8)	10 (1.6)	40 (3.0)	2 (0.7)	0 (0.1)
Lebanon	25 (2.2)	16 (1.8)	40 (2.3)	13 (2.1)	5 (0.9)
Italy	48 (3.7)	6 (1.5)	40 (3.0)	3 (0.9)	4 (1.9)

* No Response

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

As with the previous example, non-response rates were very low. Option A, that the heat capacity of metal is lower than wood, was by far the most frequently selected incorrect response. Although the heat capacity of metal is generally lower than wood, this is not an appropriate explanation for why metals typically feel colder to the touch than wood. The two other alternatives are clearly not correct: the temperatures of both materials are the same, and, in such a situation, the metal molecules do not move faster than the wood molecules.

Physics: Achievement at the High International Benchmark

Exhibit 9.7 shows a constructed-response item from the mechanics domain that anchored at the High International Benchmark. Example Item 4 required students to apply the principle that, in a collision, total mechanical energy is conserved. In the Netherlands, 81 percent of physics students answered this item correctly, 12 points higher than in Lebanon, which had the second highest performance. Students in Armenia, Sweden, Italy, Iran, and Norway did not do well on this item, with fewer than half the students answering correctly. As was shown in Exhibit 7.13, the topic of elastic and inelastic collisions was part of the intended curriculum in every participating country except the Islamic Republic of Iran, and was taught to virtually all students in those eight countries. Non-response rates on this item varied widely across countries: from 2 percent and 4 percent in the Netherlands and Slovenia, respectively, to 43 percent in Armenia and 44 percent in Italy.

Example Item 5, shown in Exhibit 9.8, is from the heat and temperature domain and it also anchored at the High International Benchmark. This multiple-choice item was designed to assess students' knowledge of the fact that heat radiation is a kind of electromagnetic radiation emitted from the surface of an object in the form of infrared light. The options for the item refer to different kinds of electromagnetic

Exhibit 9.7 **TIMSS Advanced 2008 High International Benchmark (550) of Physics Achievement – Example Item 4**

TIMSSAdvanced 2008 Physics

Content Domain: Mechanics

Description: Applies the energy law to calculate the maximum compression of a spring

A block of mass 2.0 kg travels horizontally at a speed 2.5 m/s towards a massless spring with spring constant 800 N/m. After the block collides with the spring, its speed decreases and the spring compresses. What is the maximum distance that the spring will compress? (Ignore friction and air resistance.)

Show your work.

Total mechanical energy before and after the collision is conserved.

$$\frac{1}{2}Mv^2 = \frac{1}{2}kx^2 +$$

$$\frac{1}{2} \times 2 \times (2.5)^2 = \frac{1}{2} \times 800 \times x^2$$

$$\frac{6.25}{400} = x^2$$

$$\frac{2.5}{20} = x =$$

$$x = \frac{250}{2000} = \frac{125}{1000}$$

$$0.125 \text{ m}$$

The answer shown is an example of a student response that was scored as correct

Country	Percent Correct
† Netherlands	81 (2.2)
Lebanon	69 (2.3)
‡ Slovenia	65 (3.0)
Russian Federation	52 (3.0)
Armenia	45 (3.4)
Sweden	31 (2.3)
Italy	30 (3.3)
Iran, Islamic Rep. of	29 (2.4)
Norway	19 (2.1)

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Exhibit 9.7 **TIMSS Advanced 2008 High International Benchmark (550) of Physics Achievement – Example Item 4 (Continued)**

TIMSSAdvanced 2008 Physics

Scoring Guide

Code	Response	Item: PA23072
	Correct Student Responses	
10	Uses conservation of mechanical energy, $\frac{1}{2}mv^2 = \frac{1}{2}kx^2 \rightarrow x = (0.12 - 0.14 \text{ m})$	
11	Correct reasoning but calculation error and/or missing or incorrect units.	
	Incorrect Student Responses	
70	0.025 m, based on $mg = kx$	
71	Correct answer, no work shown	
79	Other incorrect	
NR	No Response	

Country	Percent of Students in Each Scoring Guide Category					
	Correct Student Responses		Incorrect Student Responses			
	10	11	70	71	79	NR
† Netherlands	71 (2.5)	10 (1.5)	0 (0.3)	0 (0.0)	17 (2.1)	2 (0.7)
Lebanon	53 (2.3)	15 (1.8)	1 (0.6)	0 (0.0)	19 (2.0)	10 (1.5)
‡ Slovenia	53 (3.1)	12 (2.2)	4 (1.1)	0 (0.0)	28 (2.4)	4 (0.9)
Russian Federation	42 (3.0)	10 (1.6)	0 (0.1)	0 (0.1)	23 (2.2)	25 (2.4)
Armenia	43 (3.4)	2 (1.2)	0 (0.0)	0 (0.0)	12 (2.7)	43 (3.0)
Sweden	26 (2.3)	6 (1.1)	1 (0.5)	0 (0.2)	50 (2.2)	18 (2.0)
Italy	23 (3.0)	7 (1.6)	0 (0.0)	0 (0.0)	26 (3.6)	44 (3.8)
Iran, Islamic Rep. of	19 (1.8)	11 (1.4)	3 (0.8)	0 (0.0)	57 (2.5)	11 (1.6)
Norway	16 (1.8)	3 (0.8)	1 (0.5)	0 (0.0)	52 (2.5)	27 (1.7)

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Exhibit 9.8 **TIMSS Advanced 2008 High International Benchmark (550) of Physics Achievement – Example Item 5**

TIMSSAdvanced 2008 Physics

Content Domain: Heat and Temperature

Description: Identifies the type of electromagnetic radiation related to the temperature of a heat-emitting body

A satellite observes the temperatures on Earth. What type of electromagnetic radiation should the sensors be able to detect?

- (A) radio waves
- ● infrared light
- (C) visible light
- (D) ultraviolet light

Country	Percent Correct
† Netherlands	84 (2.0)
Norway	60 (2.6)
Russian Federation	59 (2.9)
‡ Slovenia	57 (2.9)
Sweden	56 (2.7)
Italy	48 (3.5)
Iran, Islamic Rep. of	37 (2.3)
Armenia	36 (3.5)
Lebanon	23 (2.2)

Country	Percent of Students				
	A	B Correct Response	C	D	NR*
† Netherlands	2 (0.7)	84 (2.0)	1 (0.6)	12 (1.7)	0 (0.0)
Norway	7 (1.1)	60 (2.6)	5 (1.0)	28 (2.0)	0 (0.0)
Russian Federation	18 (2.0)	59 (2.9)	2 (0.6)	21 (1.9)	0 (0.2)
‡ Slovenia	5 (1.3)	57 (2.9)	6 (1.3)	32 (2.5)	0 (0.0)
Sweden	10 (1.4)	56 (2.7)	5 (1.1)	30 (2.2)	0 (0.2)
Italy	16 (2.7)	48 (3.5)	8 (2.1)	25 (2.8)	3 (1.0)
Iran, Islamic Rep. of	20 (1.7)	37 (2.3)	14 (1.9)	24 (2.0)	6 (0.9)
Armenia	33 (3.5)	36 (3.5)	13 (2.7)	17 (2.9)	1 (0.6)
Lebanon	26 (2.2)	23 (2.2)	20 (2.4)	27 (2.2)	4 (1.0)

* No Response

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

radiation. Non-response rates were very low for this item, perhaps indicating that students had some degree of familiarity with the topic. Students in the Netherlands did particularly well on this item, while those in the Islamic Republic of Iran, Armenia, and Lebanon were much less successful. Many students selected alternative A (radio waves) or alternative D (ultraviolet light) as their response.

The third example of an item that anchored at the High Benchmark, Example Item 6, is from the atomic and nuclear physics domain and is shown in Exhibit 9.9. To solve this multiple-choice item, students had to be familiar with the law of radioactive decay and use their understanding of the half-life of a radioactive material to calculate the half-life of thorium. In 72 days, thorium becomes $\frac{0.25}{2.0}=\frac{1}{8}=\left(\frac{1}{2}\right)^3$ of its original mass; thus, its half-life is $72 \div 3 = 24$ days . In six countries, more than half the physics students answered this item correctly. Non-response rates were low in most countries, and alternative C (48 days) was the most popular incorrect answer choice.

Exhibit 9.9 **TIMSS Advanced 2008 High International Benchmark (550) of Physics Achievement – Example Item 6**

TIMSSAdvanced 2008 Physics

Content Domain: Atomic and Nuclear Physics

Description: Uses the law of radioactive decay to calculate the half-life of a radioactive element

A 2.0 g mass of radioactive thorium decays over 72 days, leaving 0.25 g of thorium unchanged.

What is the half-life of thorium?

Ⓐ 12 days
● 24 days
Ⓒ 48 days
Ⓓ 72 days

Country	Percent Correct
† Netherlands	88 (1.6)
Sweden	77 (1.4)
Norway	76 (1.8)
Russian Federation	65 (2.5)
‡ Slovenia	64 (1.9)
Lebanon	54 (2.3)
Armenia	44 (3.3)
Iran, Islamic Rep. of	39 (2.0)
Italy	37 (3.1)

Country	Percent of Students				
	A	B Correct Response	C	D	NR*
† Netherlands	2 (0.5)	88 (1.6)	8 (1.3)	1 (0.3)	1 (0.4)
Sweden	7 (0.8)	77 (1.4)	15 (1.3)	1 (0.4)	0 (0.3)
Norway	6 (1.0)	76 (1.8)	17 (1.2)	1 (0.4)	1 (0.3)
Russian Federation	6 (0.9)	65 (2.5)	22 (2.0)	5 (0.6)	2 (0.5)
‡ Slovenia	9 (1.2)	64 (1.9)	21 (1.5)	3 (0.8)	3 (0.7)
Lebanon	5 (0.8)	54 (2.3)	26 (1.8)	5 (0.8)	10 (1.5)
Armenia	12 (1.6)	44 (3.3)	29 (2.8)	8 (1.6)	7 (1.2)
Iran, Islamic Rep. of	8 (1.0)	39 (2.0)	22 (1.5)	4 (0.7)	27 (2.0)
Italy	8 (1.2)	37 (3.1)	35 (2.9)	5 (1.0)	15 (2.3)

* No Response

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Physics: Achievement at the Intermediate International Benchmark

Example Item 7, shown in Exhibit 9.10 is from the mechanics domain. This constructed-response item calls on students to apply their knowledge of the forces acting on a body that is thrown straight up into the air. The forces acting on the body include the Earth's gravitational force and air resistance. The Netherlands and Armenia recorded the highest performance on this item (67% correct), and four countries (Lebanon, the Russian Federation, Sweden, and Italy) had fewer than half of their physics students answering correctly. Non-response rates were below 10 percent in most countries; the 2 exceptions were Armenia (14%) and Italy (12%). Many students' responses made reference to gravitational force, but not to air resistance.

The electricity and magnetism item shown in Exhibit 9.11 is a multiple-choice item that was intended to assess students' knowledge of the various kinds of electromagnetic radiation and their wavelengths. Students from the Islamic Republic of Iran had the highest performance on this item, with 69 percent of physics students recognizing the wavelength order of four radiation types (γ-radiation, X-rays, visible light, radio waves). As with the previous item, 4 countries had fewer than half their students responding correctly: Sweden, Italy, Lebanon, and Armenia. Non-response rates on this item were very low (less than 10% in every country), and alternative D (γ-radiation, X-rays, radio waves, visible light) was the most popular incorrect answer choice almost everywhere.

Example Item 9, a multiple-choice item shown in Exhibit 9.12, is taken from the atomic and nuclear physics domain. The item assessed students' knowledge of the atomic nucleus by asking them to identify the best description of a nucleus among four given alternatives.

Exhibit 9.10 **TIMSS Advanced 2008 Intermediate International Benchmark (475) of Physics Achievement – Example Item 7**

TIMSSAdvanced2008 Physics

Content Domain: Mechanics

Description: Identifies forces acting on a body thrown up into the air

Lisa threw a small stone straight up into the air.

What forces act on the stone after it was thrown?

Earth's gravitational pull and the air resistance

The answer shown is an example of a student response that was scored as correct

Country	Percent Correct
† Netherlands	67 (2.7)
Armenia	67 (3.2)
‡ Slovenia	63 (3.0)
Iran, Islamic Rep. of	57 (2.5)
Norway	53 (2.4)
Lebanon	47 (2.7)
Russian Federation	42 (2.7)
Sweden	36 (2.6)
Italy	31 (3.5)

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Exhibit 9.10 **TIMSS Advanced 2008 Intermediate International Benchmark (475) of Physics Achievement – Example Item 7 (Continued)**

TIMSSAdvanced 2008 Physics

Scoring Guide

Code	Response	Item: PA23014
	Correct Student Response	
10	Gravity/weight and air resistance	
	Incorrect Student Responses	
70	Gravity/weight mentioned, but not air resistance	
71	Air resistance mentioned, but not gravity/weight	
79	Other incorrect	
NR	No Response	

Country	Percent of Students in Each Scoring Guide Category				
	Correct Student Response	Incorrect Student Responses			
	10	70	71	79	NR
† Netherlands	67 (2.7)	6 (1.1)	0 (0.0)	25 (2.7)	2 (1.0)
Armenia	67 (3.2)	3 (1.5)	1 (0.7)	15 (2.6)	14 (2.2)
‡ Slovenia	63 (3.0)	34 (3.1)	0 (0.0)	2 (0.8)	0 (0.0)
Iran, Islamic Rep. of	57 (2.5)	31 (2.2)	2 (0.8)	3 (0.8)	7 (1.2)
Norway	53 (2.4)	25 (2.6)	0 (0.2)	21 (2.4)	1 (0.6)
Lebanon	47 (2.7)	21 (2.0)	1 (0.6)	26 (2.3)	4 (1.0)
Russian Federation	42 (2.7)	16 (2.3)	1 (0.3)	34 (2.3)	7 (1.2)
Sweden	36 (2.6)	26 (2.4)	0 (0.0)	36 (2.2)	2 (0.6)
Italy	31 (3.5)	36 (3.5)	0 (0.2)	20 (2.7)	12 (2.1)

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Exhibit 9.11 **TIMSS Advanced 2008 Intermediate International Benchmark (475) of Physics Achievement – Example Item 8**

TIMSSAdvanced 2008 Physics

Content Domain: Electricity and Magnetism

Description: Orders types of electromagnetic radiation by wavelength

In the electromagnetic spectrum there are different types of radiation.

Which one of the following lists gives the radiation types in order of increasing wavelength?

● γ-radiation, X-rays, visible light, radio waves
Ⓑ X-rays, radio waves, visible light, γ-radiation
Ⓒ radio waves, γ-radiation, visible light, X-rays
Ⓓ γ-radiation, X-rays, radio waves, visible light

Country	Percent Correct
Iran, Islamic Rep. of	69 (2.0)
Russian Federation	58 (2.9)
Norway	56 (2.4)
† Netherlands	51 (2.4)
‡ Slovenia	50 (2.1)
Sweden	47 (2.0)
Italy	43 (2.8)
Lebanon	40 (1.9)
Armenia	38 (2.3)

Country	Percent of Students				
	A Correct Response	B	C	D	NR*
Iran, Islamic Rep. of	69 (2.0)	5 (0.7)	11 (1.3)	11 (1.2)	5 (0.8)
Russian Federation	58 (2.9)	11 (1.2)	13 (1.3)	17 (1.6)	2 (0.4)
Norway	56 (2.4)	9 (1.0)	13 (1.3)	21 (1.5)	1 (0.3)
† Netherlands	51 (2.4)	11 (1.2)	10 (1.2)	26 (1.7)	1 (0.3)
‡ Slovenia	50 (2.1)	12 (1.3)	14 (1.4)	24 (1.7)	1 (0.3)
Sweden	47 (2.0)	11 (0.9)	15 (1.7)	25 (1.9)	2 (0.4)
Italy	43 (2.8)	10 (1.3)	19 (2.0)	20 (2.4)	8 (1.2)
Lebanon	40 (1.9)	19 (1.4)	19 (1.4)	19 (1.6)	4 (0.7)
Armenia	38 (2.3)	17 (2.0)	21 (2.0)	17 (2.6)	6 (1.2)

* No Response

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Exhibit 9.12 **TIMSS Advanced 2008 Intermediate International Benchmark (475) of Physics Achievement – Example Item 9**

TIMSSAdvanced 2008 Physics

Content Domain: Atomic and Nuclear Physics

Description: Selects the best description of an atomic nucleus

Which is the BEST description of an atomic nucleus?

Ⓐ a tight group of electrons, protons, and neutrons
Ⓑ electrons and protons moving around a core of neutrons
● a tight group of protons and neutrons
Ⓓ protons moving around a core of neutrons

Country	Percent Correct
† Netherlands	93 (1.6)
Sweden	82 (2.0)
Norway	80 (2.2)
‡ Slovenia	78 (2.6)
Italy	77 (3.6)
Iran, Islamic Rep. of	76 (2.1)
Russian Federation	62 (2.4)
Armenia	50 (3.9)
Lebanon	39 (2.6)

Country	Percent of Students				
	A	B	C Correct Response	D	NR*
† Netherlands	2 (0.7)	2 (0.8)	93 (1.6)	1 (0.5)	2 (1.0)
Sweden	8 (1.4)	7 (1.3)	82 (2.0)	1 (0.6)	1 (0.5)
Norway	8 (1.6)	10 (1.4)	80 (2.2)	1 (0.6)	1 (0.6)
‡ Slovenia	11 (1.8)	7 (1.5)	78 (2.6)	4 (1.3)	0 (0.0)
Italy	7 (2.0)	12 (2.5)	77 (3.6)	2 (1.0)	2 (0.6)
Iran, Islamic Rep. of	10 (1.4)	8 (1.2)	76 (2.1)	2 (0.5)	4 (0.7)
Russian Federation	18 (1.6)	15 (1.7)	62 (2.4)	3 (0.9)	2 (0.8)
Armenia	22 (3.2)	18 (2.8)	50 (3.9)	8 (2.1)	2 (1.2)
Lebanon	17 (2.1)	14 (1.8)	39 (2.6)	25 (2.2)	5 (1.1)

* No Response

† Met guidelines for sample participation rates only after replacement schools were included (see Appendix A).

‡ Did not satisfy guidelines for sample participation rates (see Appendix A).

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Performance on this item was better than on the other example items with a high of 93 percent correct in the Netherlands and with five other countries (Sweden, Norway, Slovenia, Italy, and Iran) having more than 75 percent of students recognizing that the nucleus is a tight group of protons and neutrons. Lebanon, at 39 percent correct, was the only country where the percent correct was less than 50. As with several previous items, non-response rates on this item were very low. Students were more attracted to the descriptions in alternatives A (a tight group of electrons, protons, and neutrons) and B (electrons and protons moving around a core of neutrons) than to alternative D (protons moving around a core of neutrons).

OCCASVS
CREPVSCVLVM
8
9
10
12