TIMSS

IEA's Third International Mathematics and Science Study

Released Item Set for the Final Year of Secondary School

Mathematics and Science Literacy, Advanced Mathematics, and Physics

Overview of TIMSS

TIMSS is a collaborative research project sponsored by the International Association for the Evaluation of Educational Achievement (IEA). In 1994-95, achievement tests in mathematics and science were administered to carefully selected samples of students in classrooms around the world. With more than 40 countries participating, five grades assessed in two school subjects, more than half a million students tested in more than 30 languages, and millions of open-ended responses generated, TIMSS is the largest and most ambitious study of comparative educational achievement ever undertaken.

TIMSS tested and collected contextual information about the schooling of students in the following grade levels:

- Students enrolled in the two adjacent grades that contained the largest proportion of 9-year-old students – grades 3 and 4 in many countries
- Students enrolled in the two adjacent grades that contained the largest proportion of 13-year-old students – grades 7 and 8 in many countries
- Students in their final year of secondary education. As an additional option, countries could test two special subgroups of these students:
  - Students taking advanced courses in mathematics
  - Students taking advanced courses in physics

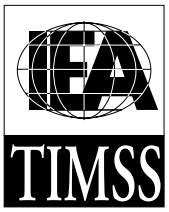
The three different groups of TIMSS students listed above are often referred to as Populations 1, 2, and 3, respectively. All countries participated in the TIMSS testing at Population 2 (grades 7 and 8), which is the core of TIMSS. Countries could choose whether or not to participate in the testing at the other two populations. Table 1 lists the 24 participants that satisfied all of the steps necessary to have their Population 3 achievement results published in the international report *Mathematics and*

Table 1

Countries Participating in Testing of Students in Their Final Year of Secondary School*

Mathematics and Science Literacy	Advanced Mathematics	Physics
• Australia	• Australia	• Australia
• Austria	• Austria	• Austria
• Canada	• Canada	• Canada
• Cyprus	• Cyprus	• Cyprus
• Czech Republic	• Czech Republic	• Czech Republic
• Denmark	• Denmark	• Denmark
• France	• France	• France
• Germany	• Germany	• Germany
• Hungary	• Greece	• Greece
• Iceland	• Israel	• Israel
• Israel	• Italy	• Italy
• Italy	• Lithuania	• Latvia
• Lithuania	• Russian Federation	• Norway
• Netherlands	• Slovenia	• Russian Federation
• New Zealand	• Sweden	• Slovenia
• Norway	• Switzerland	• Sweden
• Russian Federation	• United States	• Switzerland
• Slovenia		• United States
• South Africa		
• Sweden		
• Switzerland		
• United States		

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1994-95



Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics and Science Study.[1] The achievement results for Populations 1 and 2 were reported for 26 and 41 countries, respectively.[2]

The success of TIMSS depended on a collaborative effort between the research centers in each country, which were responsible for implementing the project, and the network of centers, responsible for managing across-country tasks such as training country representatives in standardized procedures, selecting comparable samples of schools and students, and conducting various steps required for data processing and analysis. The TIMSS International Study Center, responsible for the international coordination of tasks, is housed in the Center for the Study of Testing, Evaluation, and Educational Policy (CSTEEP) at Boston College.

The TIMSS Tests for Final-Year Students

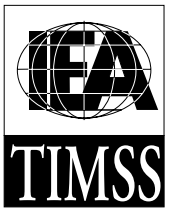
Given the extensive diversity of students' curricula there were many questions about what mathematics and science understandings students should have to meet the challenges beyond secondary school. Thus, TIMSS developed three different tests. The mathematics and science literacy test was designed for all final-year students, regardless of their school curriculum. There was also great interest on the part of some TIMSS countries to determine what school-leaving students with special preparation in mathematics and science know and can do, since the capabilities of these students may help determine a country's future potential to compete in a global economy. Thus, a second test was developed for students having taken advanced mathematics. For the sciences, it was not possible to study all branches of science in detail. The participating countries chose physics for detailed study because it is the branch of science most closely associated with mathematics, and came closest to embodying the essential elements of natural science. The third test, then, was a physics test designed to measure learning of physics concepts and knowledge among final-year students having studied physics. Not all of the 24 countries participated in the three different parts of the testing of final-year students.

The TIMSS curriculum framework underlying the mathematics and science tests at all three populations were developed by groups of mathematics and science educators with input from the TIMSS National Research Coordinators (NRCs).[3] The **content** aspect represents the subject matter content of school mathematics

[1] Mullis, I.V.S., Martin, M.O., Beaton, A.E., Gonzalez, E.J., Kelly, D.L., and Smith, T.A. (1998). *Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics and Science Study (TIMSS).* Chestnut Hill, MA: Boston College.

[2] Mullis, I.V.S., Martin, M.O., Beaton, A.E., Gonzalez, E.J., Kelly, D.L., and Smith, T.A. (1997). *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS).* Chestnut Hill, MA: Boston College; Martin, M.O., Mullis, I.V.S., Beaton, A.E., Gonzalez, E.J., Smith, T.A., and Kelly, D.L. (1997). *Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS).* Chestnut Hill, MA: Boston College; Beaton, A.E., Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., Kelly, D.L., and Smith, T.A. (1996). *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS).* Chestnut Hill, MA: Boston College; Beaton, A.E., Martin, M.O., Mullis, I.V.S., Gonzalez, E.J., Smith, T.A., and Kelly, D.L. (1996). *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS).* Chestnut Hill, MA: Boston College.

[3] The complete TIMSS curriculum frameworks can be found in Robitaille, D.F. et al. (1993). *TIMSS Monograph No. 1: Curriculum Frameworks for Mathematics and Science.* Vancouver, B.C.: Pacific Educational Press.



or science. The **performance expectation** aspect of the framework describes, in a non-hierarchical way, the many kinds of performance or behavior that might be expected of students in school mathematics or science. Conceived within the mathematics and science curriculum frameworks, test specifications were developed for three tests for final-year students.

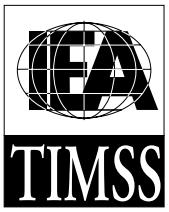
The three tests of final-year students were developed through an international consensus involving input from experts in mathematics, science, and measurement. The TIMSS Subject Matter Advisory Committee, which included distinguished scholars from 10 countries, ensured that the mathematics and science literacy tests represented current conceptions of literacy in those areas, and that the advanced mathematics and physics tests reflected current thinking and priorities in the fields of mathematics and physics. The items underwent an iterative development and review process, with multiple pilot tests. Every effort was made to ensure that the items exhibited no bias towards or against particular countries, including modifying specifications in accordance with data from the curriculum analysis component of TIMSS, obtaining ratings of the items from subject matter specialists in the participating countries, and conducting thorough statistical item analysis of data collected in the pilot testing. The final forms of the test were endorsed by the NRCs of the participating countries.[4]

The **mathematics and science literacy test** was designed to test students' general mathematical and scientific knowledge and understanding of mathematical and scientific principles.[5] The mathematics items cover number sense, including fractions, percentages, and proportionality. Algebraic sense, measurement, and estimation are also covered, as are data representation and analysis. Reasoning and social utility were emphasized in several items. A general criterion in selecting the items was that they should involve the types of mathematics questions that could arise in real-life situations and that they be contextualized accordingly. Similarly, the science items selected for use in the TIMSS literacy test were organized according to three areas of science, earth science, life science, and physical science, as well as including a reasoning and social utility component. The emphasis was on measuring how well students can use their knowledge in addressing real-world problems that have a science component. The test was designed to enable reporting for mathematics literacy and science literacy separately as well as overall.

In order to examine how well students understand advanced mathematics concepts and can apply knowledge to solve problems, the **advanced mathematics test** was developed for students in their final year of secondary school having taken advanced mathematics. This test enabled reporting of achievement overall and in three content areas: numbers, equations, and functions; calculus; and geometry. In addition to items representing these three areas, the test also included several items related to probability and statistics and to validation and structure.

[4] For a full discussion of the TIMSS tests development effort, see Garden, R.A. and Orpwood, G. (1996). "TIMSS Test Development," in M.O. Martin and D.L. Kelly (Eds.), *Third International Mathematics and Science Study Technical Report, Volume I.* Chestnut Hill, MA: Boston College; and D.F. Robitaille and R.A. Garden (Eds.), *TIMSS Monograph No. 2: Research Questions and Study Design.* Vancouver, BC: Pacific Educational Press.

[5] Information about developing the TIMSS mathematics and science literacy test in particular can be found in Orpwood, G. and Garden, R.A. (1998). *Assessing Mathematics and Science Literacy, TIMSS Monograph No. 4.* Vancouver, BC: Pacific Educational Press.



The **physics test** was developed for students in their final year of secondary school having taken physics, in order to examine how well they understand and can apply physics principles and concepts. It enabled reporting of physics achievement overall and in five content areas: mechanics; electricity and magnetism; heat; wave phenomena; and modern physics – particle physics, quantum and astrophysics, and relativity.

In each of the three tests, approximately one-third of the items were in the free-response format, requiring students to generate and write their own answers. Designed to take up about one-third of students' response time, some free-response questions asked for short answers while others required extended responses in which students needed to show their work. The remaining questions were in multiple-choice format. In scoring the tests, correct answers to most questions were worth one point. Responses to some of these questions (particularly those requiring extended responses) were evaluated for partial credit, with a fully correct answer being awarded two or three points. This was consistent with the approach of allotting students longer response time for constructed-response questions than for multiple-choice questions.

Students participating in the population 3 assessment were allowed to use calculators on all portions of the testing. Further information regarding calculator use can be found in the Population 3 achievement report, *Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics and Science Study*. In addition, reference guides of selected formulas and notations were provided at the beginning of the test booklets containing the advanced mathematics and the physics portions of the test. A copy of these guides is provided at the beginning of each appropriate section.

Table 2 presents the number and type of items included in the literacy test for mathematics and science literacy. Tables 3 and 4 present information about the items on the advanced mathematics and physics tests. As can be seen from Tables 2-4, this volume contains 35 mathematics and science literacy items, 37 advanced mathematics items, and 38 physics items.

The assessment of final-year students was accomplished by a complex design that included 12 mutually exclusive clusters of items (labeled A through L) distributed among nine booklets in a systemic fashion. The booklets were distributed to students based on their academic preparation. Each cluster could appear in more than one test booklet and, in a few cases, in different positions within the booklets. Each student completed one test booklet. Students were given 90 minutes to complete the test.

The TIMSS instruments were prepared in English and translated into the other languages used for testing. In addition, it sometimes was necessary to adapt the international versions for cultural purposes, even in the countries that tested in English. This process involved an enormous effort for the national centers with many checks along the way.

Table 2

Distribution of Mathematics and Science Literacy Items by Reporting Category[1] Population 3

Reporting Category	Number of Items	Number of Multiple-Choice Items	Number of Free-Response Items[2]
Mathematics Literacy	44 (20)	34 (12)	10 (8)
Science Literacy[3]	32 (15)	18 (3)	14 (12)
Total	76 (35)	52 (15)	24 (20)

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1995-96.

Table 3

Distribution of Advanced Mathematics Items by Content Category[1] Population 3

Content Category	Number of Items	Number of Multiple-Choice Items	Number of Free-Response Items[2]
Numbers & Equations	17 (10)	13 (6)	4 (4)
Calculus	15 (8)	12 (7)	3 (1)
Geometry	23 (13)	15 (7)	8 (6)
Probability and Statistics	7 (5)	5 (2)	2 (3)
Validation and Structure	3 (1)	2 (1)	1 (0)
Total	65 (37)	47 (23)	18 (14)

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1995-96.

[1] Figures in parentheses refer to the number of items in the released item set and provided in this volume.

[2] Free-Response Items include both short-answer and extended-response types.

[3] The data for part A of Item A-9 was deleted prior to analysis due to poor performing statistics.

Table 4

Distribution of Physics Items by Content Category[1] - Population 3

Content Category	Number of Items	Number of Multiple-Choice Items	Number of Free-Response Items[2]
Mechanics[3]	16 (9)	11 (5)	5 (4)
Electricity and Magnetism	16 (9)	10 (5)	6 (4)
Heat	9 (6)	6 (4)	3 (2)
Wave Phenomena	10 (6)	6 (2)	4 (4)
Modern Physics: Particle, Quantum and Astrophysics, and Relativity	14 (8)	9 (4)	5 (4)
Total	65 (38)	42 (20)	23 (18)

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1995-96.

[1] Figures in parentheses refer to the number of items in the released item set and provided in this volume.

[2] Free-Response Items include both short-answer and extended-response types.

[3] Item H11 was deleted prior to analysis due to poor performing statistics. It is not included in this volume.

Item Release Policy

In accordance with IEA policy, TIMSS has kept about one-third of the TIMSS items secure for possible future use in measuring international trends in mathematics and science achievement. For Population 3, the secure items are in clusters labeled B, C, E, F, I, and J. All remaining items (clusters A and D, G and H, and K and L) are available for general use. The mathematics and science literacy items are in clusters labeled A and D, the advanced mathematics items are in clusters labeled K and L, and the physics items are in clusters labeled G and H. To facilitate this use, the released TIMSS items for the final year of secondary school (Population 3) have been replicated in their entirety in this volume. This volume is divided into three sections – mathematics and science literacy, advanced mathematics, and physics.

While the purpose of this volume is to encourage the use of TIMSS items, please note the IEA copyright. Appropriate references to the IEA and TIMSS should be provided in your use of these items.

Item Documentation and Item Results

To provide a unique identifier for each item, the TIMSS cluster and item number is shown in the black box on the right hand side of each page. Across the bottom of each item, there is documentation about the item, including the subject assessed and the classification of the item by content category and performance expectation. If the item is a two-part item, the documentation for Part A is shown on the first page and the documentation for Part B is shown on the following page.

Subject

The items in this volume are divided into three parts – mathematics and science literacy, advanced mathematics, and physics.

Item Key

For multiple-choice items, the key for the correct answer is provided. For free-response questions, the categories of responses and their codes are shown on the page following the item. In scoring the TIMSS free-response questions, TIMSS utilized two-digit codes with rubrics specific to each item. The first digit designates the correctness level of the response. The first digit is usually a "1" designating a correct response, a "7" indicating an incorrect response, or a "9" for non-response. Sometimes, however, fully correct responses are differentiated from partially correct responses. In these instances, the fully correct responses are designated by a "2" (or in a few instances by a "3") and the partially correct responses by a "1." The second digit, combined with the first digit, represents a diagnostic code used to identify specific types of approaches, strategies, or common errors and misconceptions.

Content Categories

Mathematics and Science Literacy: The mathematics and science literacy items are categorized into two content areas:

- Mathematics Literacy
- Science Literacy

Table 5 indicates which items were classified as mathematics literacy and science literacy.

Advanced Mathematics: The advanced mathematics items are categorized into five content areas:

- Numbers, Equations, and Functions
- Calculus
- Geometry
- Probability and Statistics
- Validation and Structure

Table 6 indicates which advanced mathematics items were classified into each of the five content areas.

Physics: The physics items are categorized into five content areas:

- Mechanics
- Electricity and Magnetism
- Heat
- Wave Phenomena
- Modern physics - Particle, Quantum and Astrophysics, and Relativity

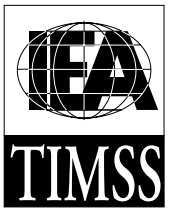
Table 7 indicates which physics items were classified into each of the five content areas.

Performance Expectation

The mathematics and science items on all three tests were classified into the following performance expectations:

Mathematics

- Knowing
- Routine Procedures
- Complex Procedures
- Solving Problems
- Justifying and Proving
- Communicating



Science

- Understanding
- Theorizing, Analyzing, and Solving Problems
- Using Tools, Routine Procedures, and Science Processes
- Investigating the Natural World

Percent of Students Responding Correctly

The percent of students responding correctly to the item reflects the international average across the countries participating in the TIMSS testing of the final-year students. That is, first the percentage of students responding correctly to the item was calculated for each country. Next, an average was calculated across countries. For the mathematics and science literacy test, this average was calculated across 21 countries, for advanced mathematics it was calculated across 16 countries, and for physics it was calculated across 16 countries. For items using a partial credit scoring scheme, the percentages given are for students responding with fully correct answers.

International Difficulty Index

This statistic reflects the difficulty of the item as estimated from item response theory (IRT). Since the TIMSS scales were developed based on the performance of students in all countries, the international scale values apply to all countries. The higher the index, the more difficult the item.

Table 5

Item Listing by Literacy Content Area

Mathematics Literacy	A03	Percentage of bicycle accidents
	A04	Expected population by year 2000
	A05	School trip participation
	A08	Data from two graphs
	A10	Draw graph relating height and age
	A12	Price of renting office space
	D06	Estimate of time to fill tank
	D07	Calories in food portion
	D08	Grapes produced per season
	D09	Price of stereo after discount
	D10	Area of shaded region
	D11	Amount of ribbon needed
	D12	Increase volume cube-shaped carton
	D13	Percentage of votes Joe received
	D14	Number of defective light bulbs
	D15A	Kelly/maximum speed of car
	D15B	Kelly/time slammed on brakes
	D16A	Total time for songs to play/estimate
	D16B	Total time for songs to play/explanation
	D17	Graph with robberies per year
Science Literacy	A01	Nuclear energy source
	A02	Effects of CFC's
	A06A	Biological control/example
	A06B	Biological control/problem
	A07	Pressure of heels on floor
	A09A	Patents per year/interpret data
	A09B	Patents per year/give reason
	A11A	Painting the bridge/reason
	A11B	Paint the bridge/consequences of new paint
	D01	Nutrition of vegetables
	D02	Impact of stone and tennis ball
	D03	José's influenza
	D04	Electrical energy and lamp
	D05A	River on the plain/good place for farming
	D05B	River on the plain/bad place for farming

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1995-96.

Table 6

Item Listing by Advanced Mathematics Content Areas

Calculus	K03	Linear acceleration of an object
	K04	Limit of a function
	K05	Derivatives
	K06	Solving an integral
	K17	Equation of a function given the derivative and point
	L05	Sum of infinite geometric series
	L06	Critical point of velocity equation
	L07	Graph of y = f(x)
Geometry	K07	Vertices of right angle triangle
	K08	Conic represented by an equation
	K09	Distance between intercepts on a plane
	K10	Angle inscribed by figures inside a semicircle
	K12	Translation of coordinates
	K14	Length of string around rod
	K18	Geometric proof of isosceles triangle
	L08	Coordinates of fourth point of a rectangle
	L09	Transformation of a rectangle
	L12	Length of diagonal in a regular hexagon
	L13	Angle between two vectors
	L17	Equation for circle
	L18	Distance between centers of two circles
Numbers, Equations and Fuctions	K01	Relationship between two variables
	K02	Permutations of books on a shelf
	K13	Growth of bacteria
	K15	Complex number solution of equations
	K16	Calculation of height of a glacier
	L01	Values of X for an inequality
	L02	Solve an equation using base *b*
	L03	Value of constant for radioactive decay
	L04	Contributions of examination question choices
	L16	Solution of real values of a quadratic equation
Probability and Statistics	K11	Probablility of number on a card
	L10	Probability of at least one alarm operating
	L14	Probability of both smoking and drinking
	L15A	Crickets/line of best fit
	L15B	Crickets/air temperature
Validation and Structure	L11	Logical deduction from series of statements

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1995-96.

Table 7

Item Listing by Physics Content Areas

Electricity and Magnetism	G01	Path of electrons traveling through a magnetic field
	G04	Relationship between induced current and varying magnetic field
	G17	Direction of force due to current
	G19	Lenz's law and falling aluminum ring
	H06	Induced emf in rotating coil
	H08	Path of electrons in electric field
	H10	Vector sum of electric forces
	H16	Speed of an electron traveling through perpendicular electric and magnetic field
	H17	Resistance of a series circuit component
Heat	G02	Volume of steam
	G03	Physical properties of two gases at the same temperature
	G11	Effect of ice melting on water level in aquarium
	H02	Liquid evaporation
	H07	Relationship between temperature and pressure with constant volume
	H14	Effect of density on the freezing of water
Mechanics	G07	Energy transformation and collision of cars
	G08	Mechanical energy of block and spring system
	G09	Direction of forces in amusement park ride
	G12	Calculation of mass using conservation of momentum
	G15	Direction of acceleration of a bouncing ball
	G16	Effect of pressure on water leaking from a bottle
	H01	Boxes sliding down inclined planes
	H04	Tension of string between two falling objects
	H13	Interpretation of a force versus distance graph
Modern Physics: Particle, Quantum and Astrophysics, and Relativity	G06	Process by which stars release energy
	G10	Minimum voltage needed to produce X-rays
	G14	Paths of alpha, beta, and gamma rays through an electric field
	G18	Alpha particles passing through gold
	H03	Photoelectric effect and kinetic energy of emitted electrons
	H05	Length of spaceship in flight
	H15	De Broglie wavelength of a mobile electron
	H18	Television as particle accelerator
Wave Phenomena	G05	Direction refracted ray of light
	G13	Doppler effect and moving car
	H09	Refraction and velocity of blue light
	H12	Particle movement in a transverse wave
	H19A	Speed of sound experiment/outline
	H19B	Speed of sound experiment/reason

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1995-96.

For More Information About TIMSS

For more details about the TIMSS results and procedures, please see the following reports:

Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics and Science Study (TIMSS). Mullis, I.V.S., Martin, M.O., Beaton, A.E., Gonzalez, E.J., Kelly, D.L., and Smith, T.A. Chestnut Hill, MA: Boston College, 1998.

Third International Mathematics and Science Study: Technical Report Volume II. M.O. Martin and D.L. Kelly (Eds.), Chestnut Hill, MA: Boston College, 1997.

Performance Assessment in IEA's Third International Mathematics and Science Study (TIMSS). Harmon, M., Smith, T.A., Martin, M.O., Kelly, D.L., Beaton, A.E., Mullis, I.V.S., Gonzalez, E.J., and Orpwood, G. Chestnut Hill, MA: Boston College, 1997.

User Guide for the TIMSS International Database: Primary and Middle School Years 1995 Assessment. E.J. Gonzalez and T.A. Smith (Eds.), Jungclaus, H., Hastedt, D., Kelly, D.L., Mullis, I.V.S., Martin, M.O., Schwippert, K., Brockmann, J., Adams, R., Foy, P., and Shen, C. Chestnut Hill, MA: Boston College, 1997.

Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS). Mullis, I.V.S., Martin, M.O., Beaton, A.E., Gonzalez, E.J., Kelly, D.L., and Smith, T.A. Chestnut Hill, MA: Boston College, 1997.

Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS). Martin, M.O., Mullis, I.V.S., Beaton, A.E., Gonzalez, E.J., Smith, T.A., and Kelly, D.L. Chestnut Hill, MA: Boston College, 1997.

Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS). Beaton, A.E., Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., Kelly, D.L., and Smith, T.A. Chestnut Hill, MA: Boston College, 1996.

Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS). Beaton, A.E., Martin, M.O., Mullis, I.V.S., Gonzalez, E.J., Smith, T.A., and Kelly, D.L. Chestnut Hill, MA: Boston College, 1996.

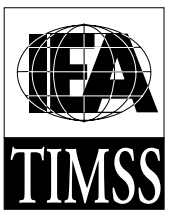
These reports can be ordered from the International Study Center at Boston College.

- To FAX Order: +1(617)552-8419
- To Phone Order: +1(617)552-4521
- To E-mail Order: timss@bc.edu

TIMSS reports and this released item set are also available on the World Wide Web:

- http://wwwcsteep.bc.edu/timss

Released Mathematics and Science Literacy Items Population 3



A3. Experts say that 25% of all serious bicycle accidents involve head injuries and that, of all head injuries, 80% are fatal.

What percentage of all serious bicycle accidents involve fatal head injuries?

A. 16%

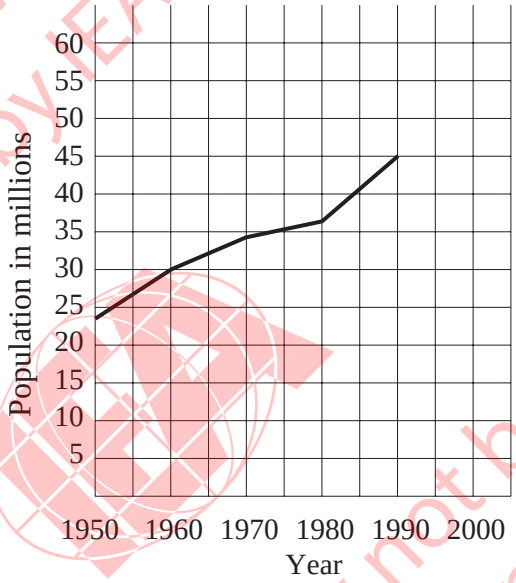
B. 20%

C. 55%

D. 105%

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	B	Mathematics Literacy	Complex Procedures	64%	488

A4. If the population increases by the same rate from the year 1990 to the year 2000 as in the years from 1980 to 1990, approximately what is the expected population by the year 2000?



A. 47 million

B. 50 million

C. 53 million

D. 58 million

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	C	Mathematics Literacy	Complex Procedures	72%	452

A5. A school club is planning a bus trip to the wildlife park. A bus which will hold up to 45 people will cost 600 centros (units of money) and admission tickets cost 30 centros each.

If the cost of the trip, including bus and admission ticket, is set at 50 centros per person, what is the minimum number of people who must participate to ensure that these costs are covered?

A. 12

B. 20

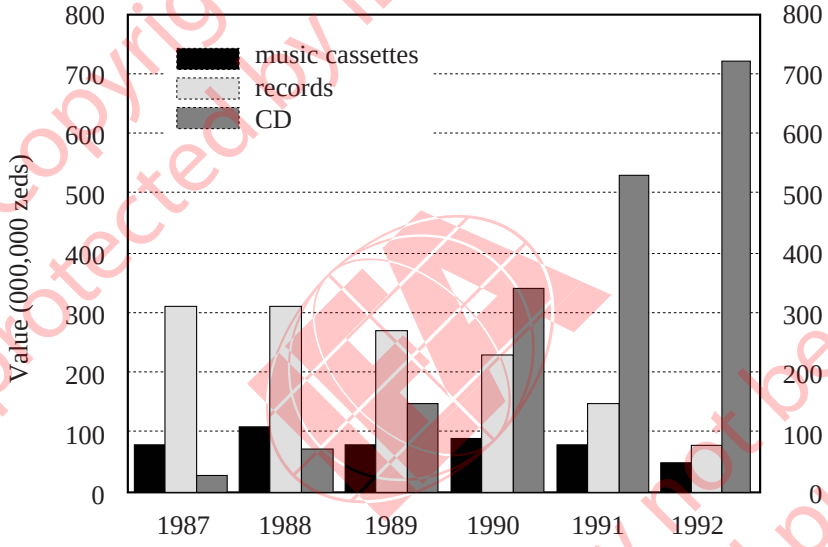
C. 30

D. 45

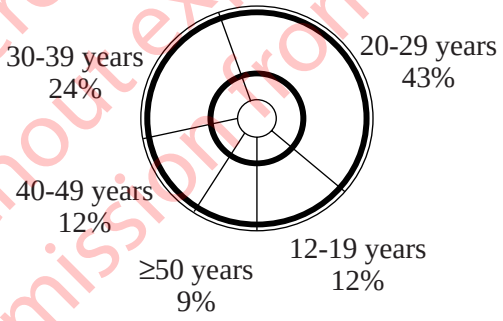
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	C	Mathematics Literacy	Solving Problems	50%	555

A8. The graphs give information about sales of CDs and other sound recording media in Zedland. Zeds are the monetary units used in Zedland.

Value of various sound recording media sold in Zedland (millions of zeds)



CD sales according to age in 1992

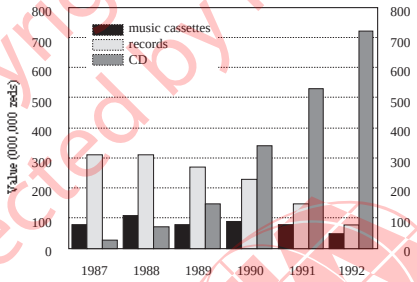


With the aid of both graphs calculate how much money was spent by 12-19 year olds on CDs in 1992. Show your work.

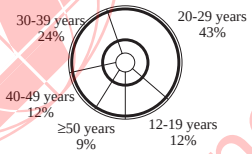
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	next page	Mathematics Literacy	Solving Problems	44%	573

A8. The graphs give information about sales of CDs and other sound recording media in Zedland. Zeds are the monetary units used in Zedland.

Value of various sound recording media sold in Zedland (millions of zeds)



CD sales according to age in 1992



With the aid of both graphs calculate how much money was spent by 12-19 year olds on CDs in 1992. Show your work.

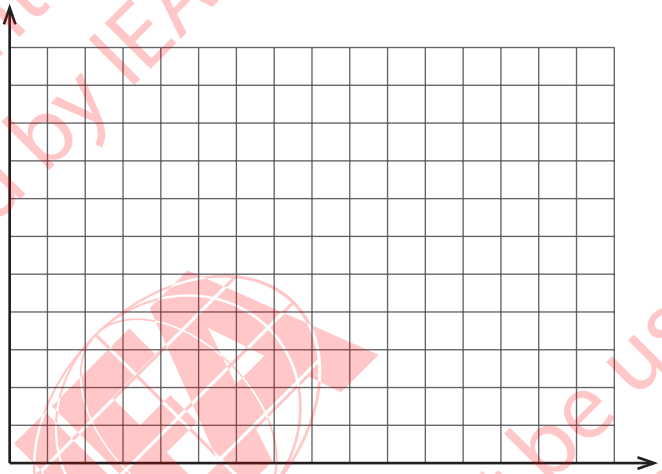
Note: Do not deduct for not including units of zeds in response.

Code	Response
	Correct Response
2 0	Answer: 86.4 million zeds (or equivalent). Explanation or method shown. *Example:* $(720 \times 1{,}000{,}000) \times (12 \div 100) = 86{,}400{,}000$
2 1	Answer in the range of 84 to 87.6 million zeds (or equivalent). Explanation or method shown.
	Partial Response
1 0	Answer in the range of 84 to 87.6 million zeds (or equivalent). No explanation or method shown.
1 1	Answer in the range of 84 to 87.6 zeds (or equivalent). Factor of 1 million is omitted. Explanation or method shown.
1 2	Answer outside range due to place value (decimal) error. Explanation or method shown. *Example:* $(710{,}000 \div 100) \times 12 = 85{,}200$
1 3	Includes some correct calculations, but final answer is missing or incorrect: *Examples: Calculation correct:* $((700$ to $730) \div 100) \times 12))$ *; no final answer. Calculation includes a computational error (other than Code 12)*
1 9	Other partial.

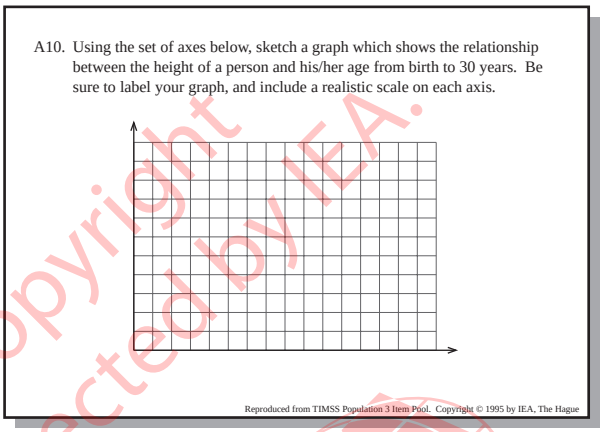
Continued Next Page

Incorrect Response	
70	Applies incorrect value of CDs. Calculates or attempts to calculate 12% of this value.
71	Applies correct value of CDs. Indicates incorrect calculation of 12%; eg. subtraction or division by 12.
79	Other incorrect.
Nonresponse	
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

A10. Using the set of axes below, sketch a graph which shows the relationship between the height of a person and his/her age from birth to 30 years. Be sure to label your graph, and include a realistic scale on each axis.



Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	next page	Mathematics Literacy	Justifying and Proving	19%	685



A10. Using the set of axes below, sketch a graph which shows the relationship between the height of a person and his/her age from birth to 30 years. Be sure to label your graph, and include a realistic scale on each axis.

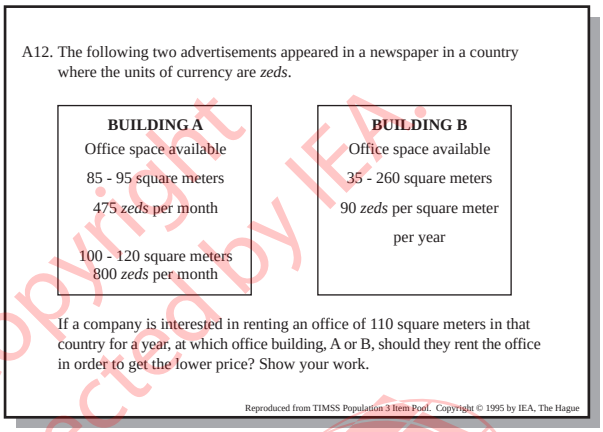
Code	Response
	Correct Response
20	All the following features correct: 1. Correct scales and labels on both axes: Age: 0 - 30 years Height: 0 - 200 cm OR 0 - 80 inches (0 - 7 ft) 2. The graph starts at approximately 50 cm (20 inches). 3. Maximum height is reached at a realistic age (14 to 20 years). 4. The graph is horizontal after age of maximum height. 5. Maximum height is reasonable.
	Partial Response
10	Incorrect start of graph. Other features correct. *Examples: Graph starts at height of zero.* *Graph does not start at year zero.*
11	Unrealistic age for maximum height. Other features correct.
12	Incorrect graph after age of maximum height. Other features correct. *Examples: Graph continuously increases in the range of 20 - 30 years.* *Graph decreases after age of maximum height.*
13	Includes incorrect scales or labels. Other features correct.
19	Other partial.
	Incorrect Response
70	Includes incorrect start of graph AND incorrect scales. Other features correct.
71	Includes incorrect start of graph AND incorrect graph after age of maximum height. Other features correct.
79	Other incorrect.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

A12. The following two advertisements appeared in a newspaper in a country where the units of currency are *zeds*.

BUILDING A	**BUILDING B**
Office space available	Office space available
85 - 95 square meters 475 *zeds* per month	35 - 260 square meters 90 *zeds* per square meter per year
100 - 120 square meters 800 *zeds* per month	

If a company is interested in renting an office of 110 square meters in that country for a year, at which office building, A or B, should they rent the office in order to get the lower price? Show your work.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	next page	Mathematics Literacy	Communicating	50%	554



A12. The following two advertisements appeared in a newspaper in a country where the units of currency are *zeds*.

BUILDING A
Office space available
85 - 95 square meters
475 *zeds* per month

100 - 120 square meters
800 *zeds* per month

BUILDING B
Office space available
35 - 260 square meters
90 *zeds* per square meter per year

If a company is interested in renting an office of 110 square meters in that country for a year, at which office building, A or B, should they rent the office in order to get the lower price? Show your work.

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Note: There is no distinction made between responses with and without units

Code	Response
	Correct Response
30	Building A. Correct calculation of rents for both buildings. 9600/800 AND 9900/825, or 825 to compare with the 800 given.
39	Other correct
	Partial Response
20	Building A. Correct calculation of rent for Building A OR B but not both.
21	Building B OR building is not named. Correct calculation of rents for both buildings.
	Minimal Response
10	Building A. Calculations or explanation are incorrect or inadequate.
11	Building A. No work shown.
12	Building B, OR building is not named. Correct calculation of rent for Building A OR B but not both.
16	Building A. Explanation is given only in the form of extracts from the advertisements.
19	Other partial.
	Incorrect Response
70	Building B. Incorrect or inadequate calculations.
71	Building B. No work shown.
79	Other incorrect.
	Nonresponse
90	Crossed out/erased, illegible, or impossible to interpret.
99	BLANK

D6. A 45 000-litre water tank is to be filled at the rate of 220 liters per minute.

Estimate, to the nearest half an hour, how long it will take to fill the tank.

A. 4 hours

B. $3\frac{1}{2}$ hours

C. 3 hours

D. $2\frac{1}{2}$ hours

D-6

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	B	Mathematics Literacy	Complex Procedures	65%	487

D7. If there are 300 calories in 100 grams of a certain food, how many calories are there in a 30 gram portion of that food?

A. 90

B. 100

C. 900

D. 1000

E. 9000

D-7

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	A	Mathematics Literacy	Knowing	71%	451

D8. In a vineyard there are 210 rows of vines. Each row is 192 m long and plants are planted 4 m apart. On average, each plant produces 9 kg of grapes each season.

The total amount of grapes produced by the vineyard each season is closest to

A. 10 000 kg

B. 100 000 kg

C. 400 000 kg

D. 1 600 000 kg

D-8

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	B	Mathematics Literacy	Complex Procedures	55%	531

D9. A store is having a '20% off' sale. The normal price of a <stereo system> is $1250.

What is the price of the <stereo system> after the 20% discount is applied?

A. $1000

B. $1050

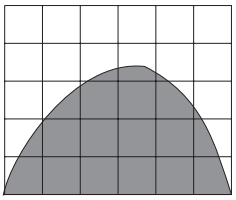
C. $1230

D. $1500

D-9

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	A	Mathematics Literacy	Routine Procedures	72%	450

D10.



Each of the small squares in the figure is 1 square unit. Which is the best estimate of the area of the shaded region?

A. 10 square units

B. 12 square units

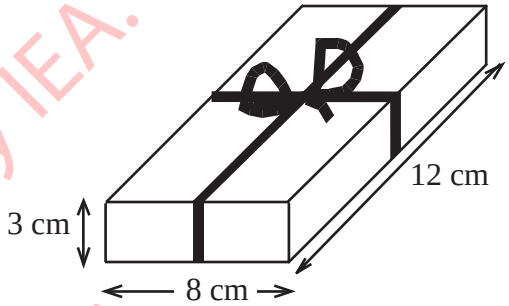
C. 14 square units

D. 16 square units

E. 18 square units

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	C	Mathematics Literacy	Knowing	61%	507

D11. Stu wants to wrap some ribbon around a box as shown and have 25 cm left to tie a bow.



How long a piece of ribbon does he need?

A. 46 cm

B. 52 cm

C. 65 cm

D. 71 cm

E. 77 cm

D-11

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	E	Mathematics Literacy	Complex Procedures	45%	575

D12. Brighto soap powder is packed in cube-shaped cartons. A carton measures 10 cm on each side.

The company decides to increase the length of each edge of the carton by 10 per cent.

How much does the volume increase?

A. 10 cm^3

B. 21 cm^3

C. 100 cm^3

D. 331 cm^3

D-12

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	D	Mathematics Literacy	Solving Problems	31%	646

D13. In a school election with three candidates, Joe received 120 votes, Mary received 50 votes, and George received 30 votes.

What percentage of the total number of votes did Joe receive?

A. 60%

B. $66\frac{2}{3}\%$

C. 80%

D. 120%

D-13

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	A	Mathematics Literacy	Routine Procedures	64%	488

D14. From a batch of 3000 light bulbs, 100 were selected at random and tested. If 5 of the light bulbs in the sample were found to be defective, how many defective light bulbs would be expected in the entire batch?

A. 15

B. 60

C. 150

D. 300

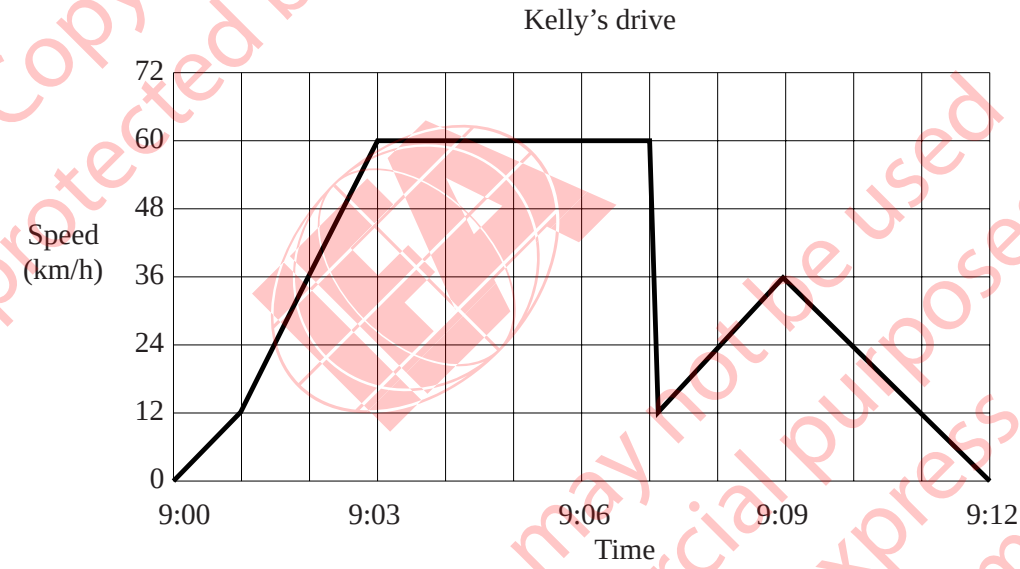
E. 600

D-14

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	C	Mathematics Literacy	Solving Problems	66%	478

D15. Kelly went for a drive in her car. During the drive, a cat ran in front of the car. Kelly slammed on the brakes and missed the cat.

Slightly shaken, Kelly decided to return home by a shorter route. The graph below is a record of the car's speed during the drive.



a) What was the maximum speed of the car during the drive?

_____

b) What time was it when Kelly slammed on the brakes to avoid the cat?

_____

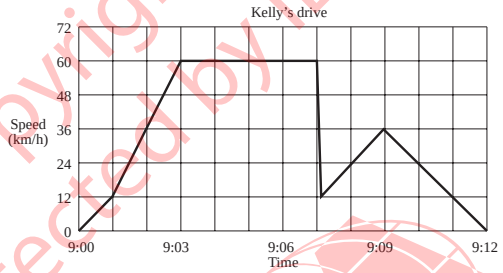
D-15a

Part a

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	next page	Mathematics Literacy	Solving Problems	74%	435

D15. Kelly went for a drive in her car. During the drive, a cat ran in front of the car. Kelly slammed on the brakes and missed the cat.

Slightly shaken, Kelly decided to return home by a shorter route. The graph below is a record of the car's speed during the drive.



a) What was the maximum speed of the car during the drive?

_____

b) What time was it when Kelly slammed on the brakes to avoid the cat?

_____

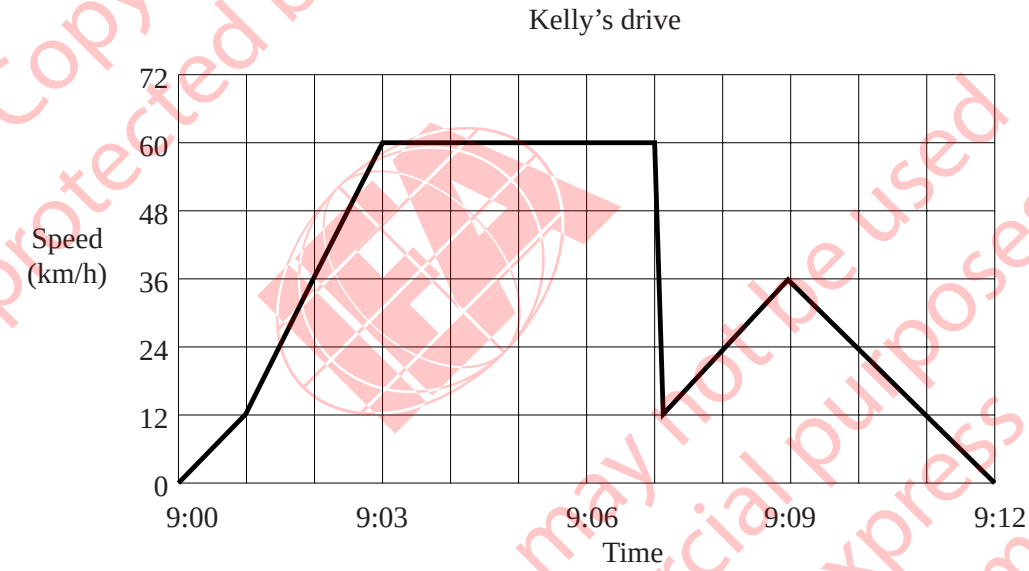
A: Codes Maximum Speed of Car

Note: Do not deduct for not including units.

Code	Response
	Correct Response
10	60 km/h.
	Incorrect Response
79	Any incorrect response.
	Nonresponse
90	Crossed-out/erased, illegible or impossible to interpret.
99	BLANK

D15. Kelly went for a drive in her car. During the drive, a cat ran in front of the car. Kelly slammed on the brakes and missed the cat.

Slightly shaken, Kelly decided to return home by a shorter route. The graph below is a record of the car's speed during the drive.



a) What was the maximum speed of the car during the drive?

_____

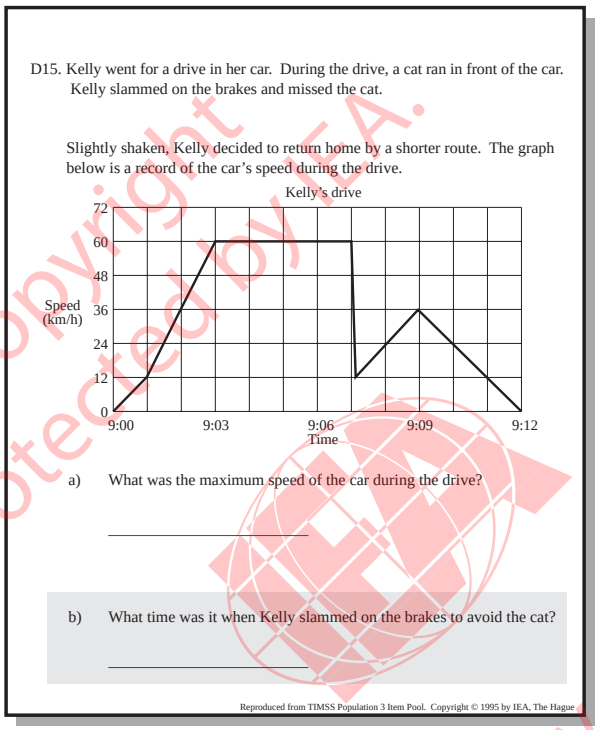
b) What time was it when Kelly slammed on the brakes to avoid the cat?

_____

D-15b

Part b

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	next page	Mathematics Literacy	Solving Problems	59%	512



D15. Kelly went for a drive in her car. During the drive, a cat ran in front of the car. Kelly slammed on the brakes and missed the cat.

Slightly shaken, Kelly decided to return home by a shorter route. The graph below is a record of the car's speed during the drive.

a) What was the maximum speed of the car during the drive?

_____

b) What time was it when Kelly slammed on the brakes to avoid the cat?

_____

B: Codes Times Slammed on Brakes

Code	Response
	Correct Response
10	9:07.
	Incorrect Response
70	9:06.
71	Answers between 9:06 and 9:07, exclusive.
72	Answers shortly after 9:07. *Examples: It was approximately 9:07 and 10 seconds, when Kelly slammed on the brakes to avoid the cat.* *Approximately 9:07 and 2 seconds.*
79	Other incorrect.
	Nonresponse
90	Crossed-out/erased, illegible or impossible to interpret.
99	BLANK

D16. Teresa wants to record 5 songs on tape. The length of time each song plays for is shown in the table.

Song	Length of Time
1	2 minutes 41 seconds
2	3 minutes 10 seconds
3	2 minutes 51 seconds
4	3 minutes
5	3 minutes 32 seconds

Estimate to the nearest minute the total time taken for all five songs to play and explain how this estimate was made.

Estimate: _____

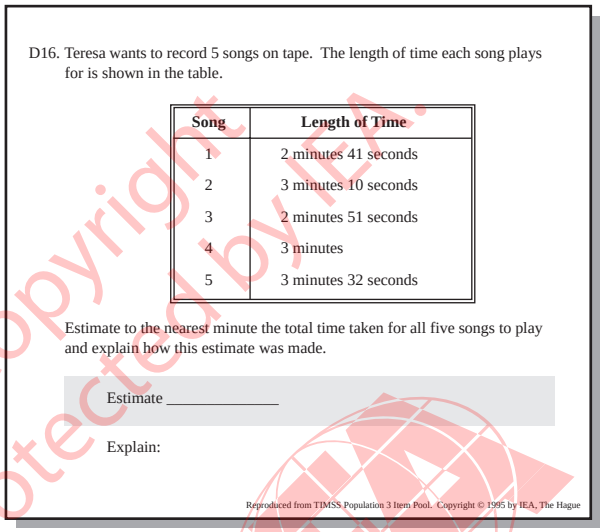
Explain:

D-16a

Estimate

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	next page	Mathematics Literacy	Solving Problems	39%	600

D-16a Coding Guide



D16. Teresa wants to record 5 songs on tape. The length of time each song plays for is shown in the table.

Song	Length of Time
1	2 minutes 41 seconds
2	3 minutes 10 seconds
3	2 minutes 51 seconds
4	3 minutes
5	3 minutes 32 seconds

Estimate to the nearest minute the total time taken for all five songs to play and explain how this estimate was made.

Estimate _____

Explain:

A: Codes for Total Estimate

Code	Response
	Correct Response
10	15 minutes
11	16 minutes
	Incorrect Response
70	13 minutes
71	14 minutes
72	15 min. 14 sec
73	17 minutes
79	Other incorrect
	Nonresponse
90	Crossed out/erased, illegible, or impossible to interpret.
99	BLANK

D16. Teresa wants to record 5 songs on tape. The length of time each song plays for is shown in the table.

Song	Length of Time
1	2 minutes 41 seconds
2	3 minutes 10 seconds
3	2 minutes 51 seconds
4	3 minutes
5	3 minutes 32 seconds

Estimate to the nearest minute the total time taken for all five songs to play and explain how this estimate was made.

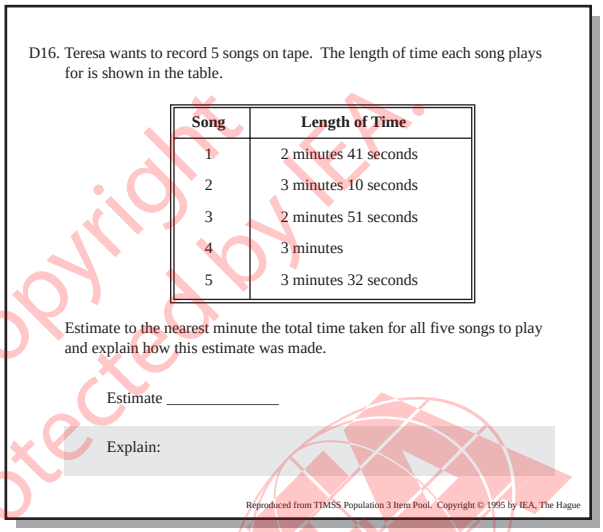
Estimate: _____

Explain:

D-16b

Explain

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	next page	Mathematics Literacy	Solving Problems	32%	635



D16. Teresa wants to record 5 songs on tape. The length of time each song plays for is shown in the table.

Song	Length of Time
1	2 minutes 41 seconds
2	3 minutes 10 seconds
3	2 minutes 51 seconds
4	3 minutes
5	3 minutes 32 seconds

Estimate to the nearest minute the total time taken for all five songs to play and explain how this estimate was made.

Estimate _____

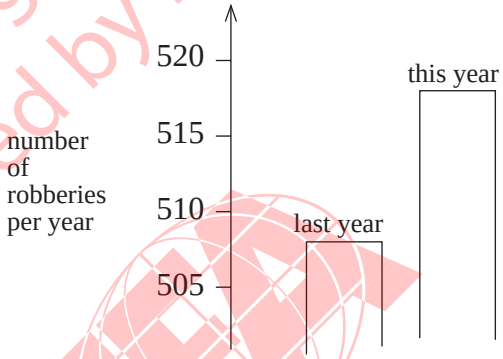
Explain:

B: Codes for Explanation

Code	Response
	Correct Response
10	Each amount of time is correctly rounded to whole minutes before adding. *Example:* *3 + 3 + 3 + 3 + 4 OR* *3 + 3 + 3 + 3 + 3*
11	Each amount of time is correctly rounded to nearest 5,10,15 or 30 seconds.
12	No calculation shown. Statements may include “rounded off to nearest minute”, “rounded the numbers up and down” or similar expressions.
13	Adds correctly and then rounds off from 15 min. 14 sec.
19	Other correct.
	Incorrect Response
70	Each amount of time is rounded off, but one or more rounding is incorrect.
71	Rounds off from 14 min. 34 sec.
79	Other incorrect
	Nonresponse
90	Crossed out/erased, illegible, or impossible to interpret.
99	BLANK

D17. A TV reporter showed this graph and said:

"There's been a huge increase in the number of robberies this year."



Do you consider the reporter's statement to be a reasonable interpretation of the graph? Briefly explain.

D-17

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Mathematics Literacy	next page	Mathematics Literacy	Knowing	19%	681

D17. A TV reporter showed this graph and said:

"There's been a huge increase in the number of robberies this year."

Do you consider the reporter's statement to be a reasonable interpretation of the graph? Briefly explain.

Note: The use of NO in these codes includes all statements indicating that the interpretation of the graph is NOT reasonable. YES includes all statements indicating that the interpretation is reasonable.

Code	Response
	Correct Response
20	NO. Focuses on the fact that only a small part of the graph is shown. *Examples: Not reasonable. The entire graph should be displayed.* *I don't think it is a reasonable interpretation of the graph because if they were to show the whole graph you would see that there is only a slight increase in robberies.*
21	NO. Contains correct arguments in terms of ratio or percentage increase. *Examples: Not reasonable. 10 is not a huge increase compared to a total of 500.* *No. According to the percentage, the increase is only about 2%.*
29	Other correct.

Continued Next Page

Partial Response	
10	NO. No explanation given.
11	NO. Focuses ONLY on an increase given by the exact number of robberies. *Examples: Not reasonable. It increased by 10 robberies.* *The word "huge" does not explain the reality of the increased number of robberies. The increase was only about 10 and I wouldn't call that "huge."*
12	NO. Focuses on the size of increase WITHOUT THE USE OF NUMBERS. *Example: Not reasonable. There has been an increase, but not a huge increase.*
13	NO. Indicates that the graph is misleading, but fails to point out the crucial features. *Examples: Not reasonable. The scale on the y-axis is misleading.* *No, it only looks like a huge amount because of huge bars and far apart distances.* *No, because it only appears that there was an increase of about 10 robberies. The T.V. guy misinterpreted the graph; he never read the axis.*
14	NO. Explanation consists of irrelevant arguments. *Example: No, because the previous year may have been just as high or higher but on the other hand it could be because the crime rate is becoming outrageous.*
19	Other partial.
Incorrect Response	
70	YES. No explanation given.
71	YES. Focuses on the increase in the exact number of robberies. *Examples: Reasonable interpretation. The increase is about 10.* *Yes, because as you can see from the graph, last year there were about 508 robberies and this year there were about 518. There were about 10 more robberies this year than last.*
72	YES. Focuses on the appearance of the graph.
73	Includes arguments, but no conclusions are drawn.
79	Other incorrect.
Nonresponse	
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

A1. Nuclear energy can be generated by fission or fusion. Fusion is not currently being used in reactors as an energy source. Why is this?

A. The scientific principles on which fusion is based are not yet known.

B. The technological processes for using fusion safely are not developed.

C. The necessary raw materials are not readily available.

D. Waste products from the fusion process are too dangerous.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	B	Science Literacy	Understanding	40%	619

A2. CFCs (chlorofluorocarbons) revolutionized personal and industrial life for 30 years. They were the coolant in refrigerators and the propellants in aerosols, pressure packs and fire extinguishers. There are now very strong international moves to stop the use of these substances because

A. they are chemically inert.

B. they contribute to the greenhouse effect.

C. they are poisonous to humans.

D. they destroy the ozone layer.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	D	Science Literacy	Understanding	77%	417

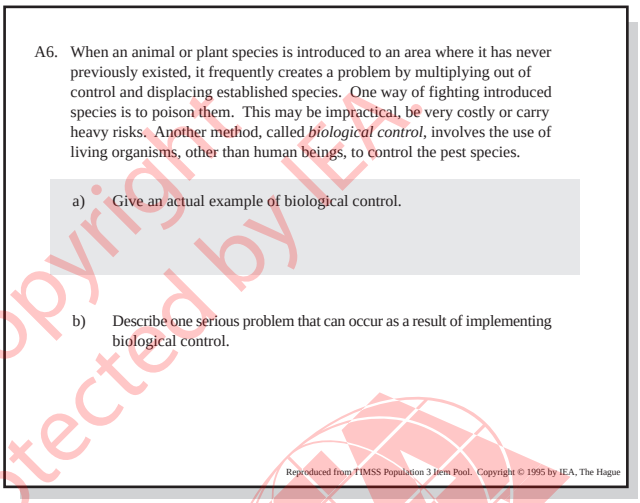
A6. When an animal or plant species is introduced to an area where it has never previously existed, it frequently creates a problem by multiplying out of control and displacing established species. One way of fighting introduced species is to poison them. This may be impractical, be very costly or carry heavy risks. Another method, called *biological control*, involves the use of living organisms, other than human beings, to control the pest species.

a) Give an actual example of biological control.

b) Describe one serious problem that can occur as a result of implementing biological control.

Part a

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Understanding	37%	631



A6. When an animal or plant species is introduced to an area where it has never previously existed, it frequently creates a problem by multiplying out of control and displacing established species. One way of fighting introduced species is to poison them. This may be impractical, be very costly or carry heavy risks. Another method, called *biological control*, involves the use of living organisms, other than human beings, to control the pest species.

a) Give an actual example of biological control.

b) Describe one serious problem that can occur as a result of implementing biological control.

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A: Codes for Example

Note: Correct responses do not have to include specific examples of species.

Code	Response
	Correct Response
10	Introducing species which eat the pests. *Examples: Have a house cat in your house to rid mice as a biological control.* *Ladybugs are introduced to eat aphids.* *To control several different pests on plants, living organisms that feed on those could be introduced.* *Birds eat bugs, so if you have a bug problem get birds.*
11	Introducing species which parasitise pests. *Example: Ichneumon flies lay their eggs in caterpillars, which then die.*
12	Transmitting infection (viruses/bacteria) to the pests. *Example: Myxomatosis is introduced to kill rabbits.*
19	Other correct.
	Incorrect Response
70	Includes chemical control.
71	Incomplete: omits one of the species involved; i.e. mentions either the controlled or the controlling organism, but not both. *Example: Hawk.*
76	Merely repeats information given in stem.
79	Other incorrect. *Example: Protect some animals from the other one when they are in the minority.*
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

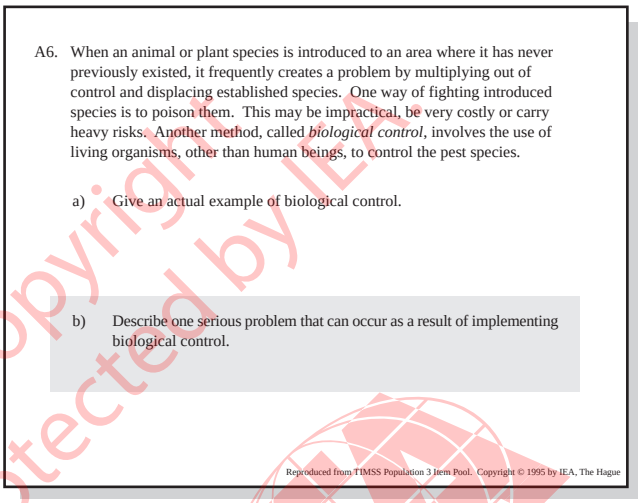
A6. When an animal or plant species is introduced to an area where it has never previously existed, it frequently creates a problem by multiplying out of control and displacing established species. One way of fighting introduced species is to poison them. This may be impractical, be very costly or carry heavy risks. Another method, called *biological control*, involves the use of living organisms, other than human beings, to control the pest species.

a) Give an actual example of biological control.

b) Describe one serious problem that can occur as a result of implementing biological control.

Part b

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Understanding	44%	594



A6. When an animal or plant species is introduced to an area where it has never previously existed, it frequently creates a problem by multiplying out of control and displacing established species. One way of fighting introduced species is to poison them. This may be impractical, be very costly or carry heavy risks. Another method, called *biological control*, involves the use of living organisms, other than human beings, to control the pest species.

a) Give an actual example of biological control.

b) Describe one serious problem that can occur as a result of implementing biological control.

B: Codes for Problem

Code	Response
	Correct Response
10	Control organism itself may grow out of control. With or without examples. *Example: This could get out of hand and the other species may begin to overrun the other ones and they will have to implement a new species to control them.*
11	Control organism may attack other organisms than the one it was introduced to control. With or without examples.
12	Control organism may completely destroy or cause the extinction of the organism it was introduced to control. With or without examples. *Example: One serious problem might be the death of a species. The species brought to control could kill off the species it is controlling.*
13	An ecological imbalance may be created. With or without examples. *Example: The whole ecosystem may become imbalanced if first one, then another species is introduced.*
14	Any combination of Codes 10, 11, 12 or 13. *Example: One problem is that the spiders would be multiplying very rapidly because of the food source and environment. They may destroy all the insects and end up having nothing to eat and eventually kill themselves, which would destroy the whole environment.*
19	Other correct.
	Incorrect Response
79	Any unacceptable response. *Examples: You can add another problem that would create the same problem.* *Reproduction higher for some animals*
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

A7. Some high heeled shoes are claimed to damage floors. The base diameter of these very high heels is about 0.5 cm and of ordinary heels about 3 cm. Briefly explain why the very high heels may cause damage to floors.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Theorizing, Analyzing, and Solving Problems	41%	596

A7. Some high heeled shoes are claimed to damage floors. The base diameter of these very high heels is about 0.5 cm and of ordinary heels about 3 cm. Briefly explain why the very high heels may cause damage to floors.

Note: Do not deduct for mistakes in the ratio of the areas or pressures (even if they are extreme).

Code	Response
	Correct Response
20	Refers to greater pressure on the floor because of smaller area of the heels. *Examples: The pressure from the heel is greater because the area is smaller.* *Because of the narrow diameter of very high heels, all the body weight is spread over a greater area. There is greater pressure exerted on the floor with the higher heels because it is all placed on a small area. The pressure is less on a wider heel because the weight is distributed over a greater area causing less damage.*
21	Refers to weight or force acting on smaller area or heel size, without using the term pressure. *Examples: The weight is distributed over a smaller area.* *The heels have a very small point on the shoes. It is holding the same amount of weight as much wider heels. This causes dents in the floor.*
29	Other correct.
	Partial Response
10	Refers to greater pressure without mentioning area of the heels.
11	Refers to an increasing "force" instead of "pressure" with a smaller area. *Example: The force increases as the area of the heel gets smaller.*
12	Misuse of "pressure" instead of "force" but correct thinking. *Examples: The pressure is distributed over a smaller area.* *There is more direct pressure on a smaller surface area of the floor with very high heels, while ordinary heels put pressure on the floor that is more spread or not so concentrated.*
13	Misuse of "mass" instead of "force" or "weight" but correct thinking. *Example: The mass is distributed over a smaller area.*
19	Other partial. *Example: The weight on .5 cm heel is more forceful than on an evenly balanced 3 cm heel.*

Continued Next Page

	Incorrect Response
70	Refers only to the hardness of the material or sharpness of high heels. *Examples: They are made of much harder material like steel.* *Because they are sharper and they poke into the floor.*
76	Merely repeats information in the stem. *Example: They have a smaller area, that's why they cause damage to floors.*
79	Other incorrect.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

A9. One measure of a country's industrial creativity that is sometimes used is the number of patents applied for annually relative to the number of researchers in the country. (Note: a patent is the legal right to exclusive use of a new idea, product or process.) The following table shows these data for six countries:

Measurement of industrial creativity

Country	Number of patent applications per year	Number of researchers	Number of patents applied for per year per researcher
Austria	2 600	23 000	0.11
Canada	1 850	52 600	0.03
France	14 000	139 000	0.10
Germany	33 000	270 000	0.12
Japan	78 500	386 000	0.19
USA	76 000	752 000	0.10

(Source: Science Council of Canada, 1983)

a) Do these data support each of the following statements?
(Circle either Yes or No for each .)

1: The more researchers a country has, the more patents will be applied for. YES NO

2: German industrial research is superior to that in the U.S.A. YES NO

b) Give one reason why the number of patents applied for per year per researcher may or may not be a good measure of a country's industrial creativity.

Part a

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
	Data for part A of Item A-9 was deleted prior to analysis due to poor performing statistics.				

A9. One measure of a country's industrial creativity that is sometimes used is the number of patents applied for annually relative to the number of researchers in the country. (Note: a patent is the legal right to exclusive use of a new idea, product or process.) The following table shows these data for six countries:

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(Source: Science Council of Canada, 1983)

a) Do these data support each of the following statements?
(Circle either Yes or No for each .)

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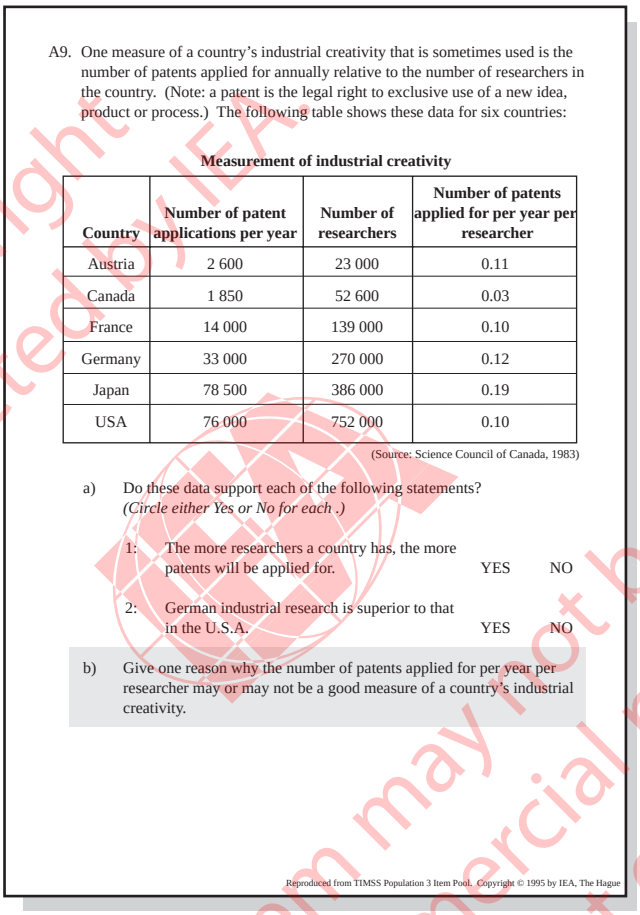
2: German industrial research is superior to that in the U.S.A. YES NO

b) Give one reason why the number of patents applied for per year per researcher may or may not be a good measure of a country's industrial creativity.

Part b

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Using Tools, Routine Procedures, and Science Processes	33%	660



A9. One measure of a country's industrial creativity that is sometimes used is the number of patents applied for annually relative to the number of researchers in the country. (Note: a patent is the legal right to exclusive use of a new idea, product or process.) The following table shows these data for six countries:

Measurement of industrial creativity

Country	Number of patent applications per year	Number of researchers	Number of patents applied for per year per researcher
Austria	2 600	23 000	0.11
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Japan	78 500	386 000	0.19
USA	76 000	752 000	0.10

(Source: Science Council of Canada, 1983)

a) Do these data support each of the following statements? *(Circle either Yes or No for each .)*

1: The more researchers a country has, the more patents will be applied for. YES NO

2: German industrial research is superior to that in the U.S.A. YES NO

b) Give one reason why the number of patents applied for per year per researcher may or may not be a good measure of a country's industrial creativity.

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B: Codes Reason May or May not be Good Measure

Code	Response
	Correct Response
10	Supports the suggested ratio as a good measure of creativity and provides any logical reason.
11	Does NOT support the suggested ratio as a good measure of creativity; refers to lack of information about quality or significance of patents. *Example: Because maybe the patents aren't as good as a country without so many patents.*
12	Does NOT support the suggested ratio as a good measure of creativity; refers to development occurring without patents applied for. *Example: This chart has no bearing as to how much industrial creativity was produced by the end of the year.*
13	Does NOT support the suggested ratio as a good measure of creativity; refers to policy and/or lack of opportunity impeding implementation of developments.
14	Does NOT support the suggested ratio as a good measure of creativity; refers to non-representative data in table. *Examples: The data in the table may come from a year where there were more applications than normal.* *One country may not have had very many one year because of lots the year before.* *This statistic is not a good measure of a country's industrial creativity because patents may be more difficult to apply for in one country than another.*

Continued Next Page

	Correct Response
19	Other logical reasons not supporting the suggested ratio as a good measure of creativity. *Examples: Patents applied for is not the same as patents granted.* *This chart doesn't say whether or not they had actually received these patents.*
	Incorrect Response
70	Suggests a better measure, but does not explain why. *Example: Countries may be helping each other out.*
71	Any statement not supported by a logical reason. *Examples: It is unfair.* *The graph is biased. It does get both sides of the situation.* *Lots of people have good ideas but don't think they are good.*
79	Other incorrect.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

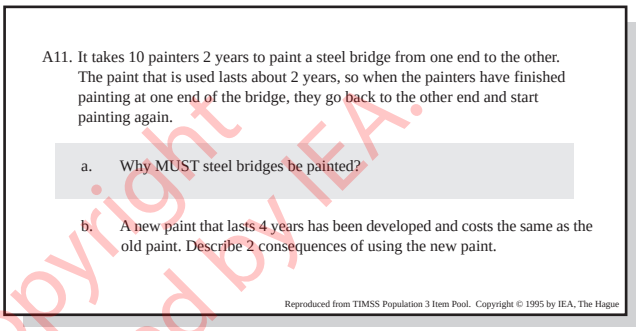
A11. It takes 10 painters 2 years to paint a steel bridge from one end to the other. The paint that is used lasts about 2 years, so when the painters have finished painting at one end of the bridge, they go back to the other end and start painting again.

a. Why MUST steel bridges be painted?

b. A new paint that lasts 4 years has been developed and costs the same as the old paint. Describe 2 consequences of using the new paint.

Part a

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Theorizing, Analyzing, and Solving Problems	74%	436



A11. It takes 10 painters 2 years to paint a steel bridge from one end to the other. The paint that is used lasts about 2 years, so when the painters have finished painting at one end of the bridge, they go back to the other end and start painting again.

a. Why MUST steel bridges be painted?

b. A new paint that lasts 4 years has been developed and costs the same as the old paint. Describe 2 consequences of using the new paint.

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A: Codes Reason for Painting

Code	Response
	Correct Response
10	Explicitly refers to rusting or corrosion.
19	Other correct.
	Incorrect Response
70	Mentions only aesthetic reasons. *Examples: It looks nicer.* *It is ugly.*
71	Refers to protecting or improving the bridge for reasons other than code 10 above: *Examples: The paint must be renewed.* *It is a long time since it was painted.*
72	Any combination of codes 70, 71.
73	Challenges the information in the question. *Example: You don't need to paint steel bridges.*
79	Other incorrect.
	Nonresponse
90	Crossed out/erased, illegible, or impossible to interpret.
99	BLANK

A11. It takes 10 painters 2 years to paint a steel bridge from one end to the other. The paint that is used lasts about 2 years, so when the painters have finished painting at one end of the bridge, they go back to the other end and start painting again.

a. Why MUST steel bridges be painted?

b. A new paint that lasts 4 years has been developed and costs the same as the old paint. Describe 2 consequences of using the new paint.

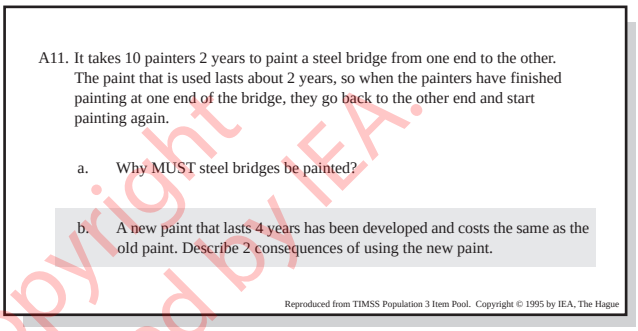
First Consequence

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Theorizing, Analyzing, and Solving Problems	64%	496

Second Consequence

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Theorizing, Analyzing, and Solving Problems	46%	587

Part b



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a. Why MUST steel bridges be painted?

b. A new paint that lasts 4 years has been developed and costs the same as the old paint. Describe 2 consequences of using the new paint.

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B: Codes Painting Lasting 4 Years

Note: Each of the two consequences must be coded separately.
The same codes can be used twice.
However, if the consequences described are essentially the same, the second should be coded as 79.
Example: They don't need to go back and start again. (code 11) The can wait before they start paining again. (code 79)

Code	Response
	Correct Response
10	Student includes the fact that there is more profit [for the painting company or the community]. *Examples: It is cheaper for the company* *Less painters are needed.* *They can paint more bridges.*
11	The painters don't need to paint so often or work so hard. *Examples: They can wait two years before starting again.* *Longer vacations for the workers.* *They can have another job in the meantime.*
12	Mentions increased unemployment or lower salary for the workers.
19	Other correct: *Example: Fewer problems for the traffic.*
	Incorrect Response
70	The paint will last for a longer time.
76	Merely repeats information in the stem. *Examples: It will last for four years.* *It will cost the same*
79	Other incorrect.
	Nonresponse
90	Crossed out/erased, illegible, or impossible to interpret.
99	BLANK

D1. It is often claimed that "cooked vegetables are not as nutritious as the same kinds of vegetables uncooked." What could be done to find out if this statement is true?

A. Compare the weight of the vegetables before and after they are cooked.

B. Compare the colour of the cooked and uncooked vegetables.

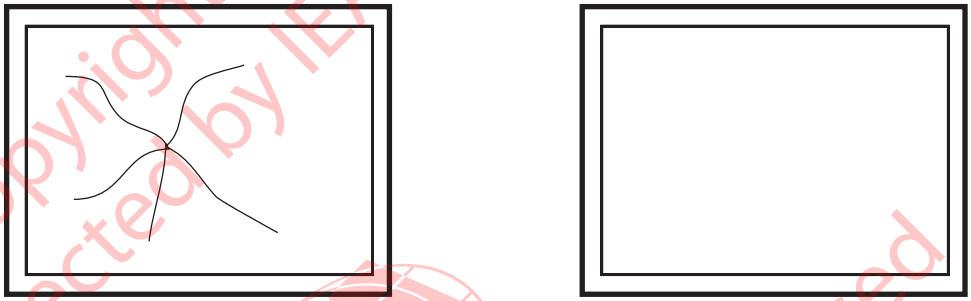
C. Test the acidity of the water in which the vegetables are cooked.

D. Compare the vitamin content of the cooked and uncooked vegetables.

D-1

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	D	Science Literacy	Investigating the Natural World	87%	337

D2. The sketch below shows two windows. The left window has been cracked by a flying stone. A tennis ball, with the same mass and speed as the stone, strikes the adjacent, similar window, but does not crack it.

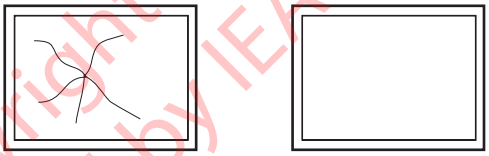


What is one important reason why the impact of the stone cracks the window but the impact of the tennis ball does not?

D-2

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Theorizing, Analyzing, and Solving Problems	57%	528

D2. The sketch below shows two windows. The left window has been cracked by a flying stone. A tennis ball, with the same mass and speed as the stone, strikes the adjacent, similar window, but does not crack it.



What is one important reason why the impact of the stone cracks the window but the impact of the tennis ball does not?

Code	Response
	Correct Response
20	Refers to collision time or longer impact time and (therefore) smaller force for ball than stone.
21	Refers to kinetic energy of the ball being used partly to compress the ball and kinetic energy of the stone being used to break the glass, since the stone cannot be compressed. *Example: The surface area struck is greater on the tennis ball than on the stone. Also the structure of the object thrown: the rock is hard and penetrates the glass causing the crack, but the ball is soft and when it strikes the window is absorbs some of its own velocity and rebounds back.*
	Partial Response
10	Refers to the softness or deformation of the ball versus the hardness or solidness of the stone without mentioning kinetic energy. *Examples: The ball has give and the rock does not. A tennis ball is rubber and changes shape when it hits; a rock is hard solid and does not change shape.* *The tennis ball is not solid and has a soft outside. The rock is hard and solid.* *The tennis ball has air or a hollow inside, giving it some leeway when it hits the window, but the rock is solid and just hits with full force.*
11	Refers to the larger impact area of the ball versus the smaller area or higher density of the stone, which gives a more concentrated force on impact. *Examples: The tennis ball hits a larger area, spreading the blow across the window.* *The size of the stone is smaller causing less surface area to strike the window, whereas the tennis ball has a larger surface area causing it to even out the absorption.*
19	Other partial.

Continued Next Page

	Incorrect Response
70	Refers only to differences in mass/weight or density.
72	Refers only to the “sharpness” of the stone. *Examples: The shape of the stone has ridges and edges and can crack things.*
76	Merely repeats information in the stem.
79	Other incorrect.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

D3. José caught influenza. Write down one way he could have caught it.

D-3

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Understanding	68%	475

D-3 Coding Guide

D3. José caught influenza. Write down one way he could have caught it.

Code	Response
	Correct Response
10	Refers explicitly to transmission of germs.
11	Refers implicitly to transmission of germs by sneezing/coughing or close contact. *Examples: Drinking from the same cup.* *Shaking hands.* *Eating together or from same utensils.*
12	States only that he got it from someone who had the flu.
19	Other correct.
	Incorrect Response
70	Refers to being too cold. *Examples: He got it from being out in the cold.* *He got it from getting wet [or freezing].* *He got it because he did not wear enough clothes.*
79	Other incorrect.
	Nonresponse
90	Crossed out/erased, illegible, or impossible to interpret.
99	BLANK

D4. Electrical energy is used to power a lamp.

Is the amount of light energy produced more than, less than, or the same as the amount of electrical energy used?

The amount of light energy produced is

____ more than

____ less than (check one)

____ the same as

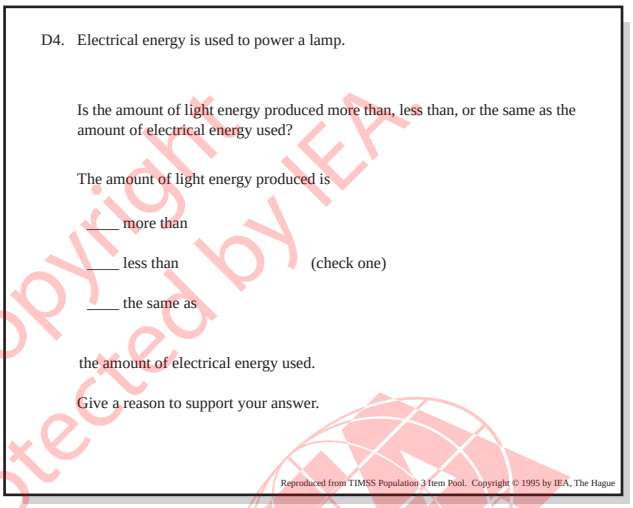
the amount of electrical energy used.

Give a reason to support your answer.

D-4

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Theorizing, Analyzing, and Solving Problems	21%	727

D-4 Coding Guide



D4. Electrical energy is used to power a lamp.

Is the amount of light energy produced more than, less than, or the same as the amount of electrical energy used?

The amount of light energy produced is

____ more than

____ less than (check one)

____ the same as

the amount of electrical energy used.

Give a reason to support your answer.

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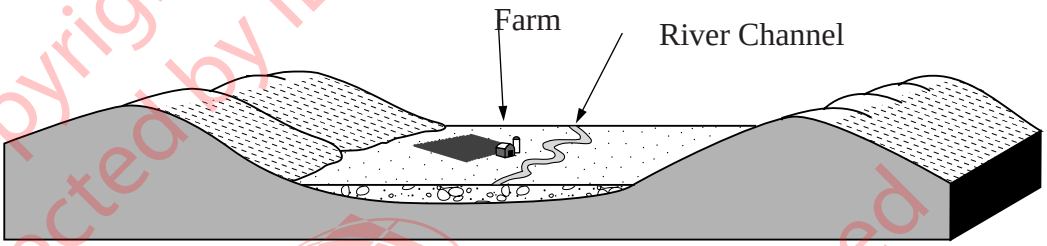
Code	Response
	Correct Response
20	Less. Mentions that (much) energy is transformed to heat.
21	Less. Mentions that energy is needed to warm up the lamp.
22	Less. Mentions that energy (heat) is lost to the surroundings.
29	Less. Other correct.
	Partial Response
10	Less. No explanation.
11	Less. Energy is lost in transport. *Example: Electricity is lost in the wire*
19	Other partially correct: Less. Other erroneous explanations.
	Incorrect Response
70	The same. With erroneous explanation. *Examples: Energy is always preserved.* *When the sun is out you don't need electrical energy.*
71	The same. No explanation is given.
72	More. With or without explanation.
79	Other incorrect.
	Nonresponse
90	Crossed out/erased, illegible, or impossible to interpret.
99	BLANK

D5. The diagram shows a river flowing through a wide plain. The plain is covered with several layers of soil and sediment.



a. Write down one reason why this plain is a good place for farming.

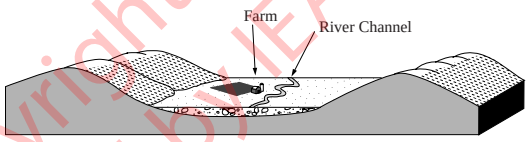
b. Write down one reason why this plain is NOT a good place for farming.

D-5a

Part a

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Theorizing, Analyzing, and Solving Problems	72%	440

D5. The diagram shows a river flowing through a wide plain. The plain is covered with several layers of soil and sediment.



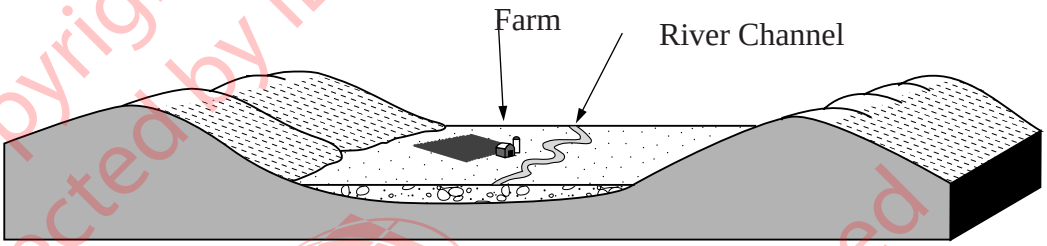
a. Write down one reason why this plain is a good place for farming.

b. Write down one reason why this plain is NOT a good place for farming.

A: Codes Good Place

Code	Response
	Correct Response
10	Mentions that the soil is fertile (good), abundant.
11	Mentions that there is a river (for irrigation, water for animals).
12	Mentions that there is plenty of space or flat areas for farm land.
19	Other correct: *Example: The goats can find grass in the mountains.*
	Incorrect Response
70	Does not address the issue of farming. *Examples: It is silent, a peaceful place to live.* *You can swim in the river.*
76	Merely repeats information in stem.
79	Other incorrect.
	Nonresponse
90	Crossed out/erased, illegible, or impossible to interpret.
99	BLANK

D5. The diagram shows a river flowing through a wide plain. The plain is covered with several layers of soil and sediment.



a. Write down one reason why this plain is a good place for farming.

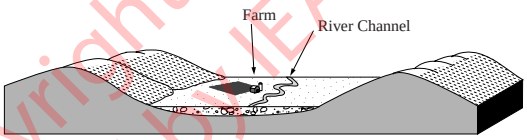
b. Write down one reason why this plain is NOT a good place for farming.

D-5b

Part b

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Science Literacy	next page	Science Literacy	Theorizing, Analyzing, and Solving Problems	51%	558

D5. The diagram shows a river flowing through a wide plain. The plain is covered with several layers of soil and sediment.



a. Write down one reason why this plain is a good place for farming.

b. Write down one reason why this plain is NOT a good place for farming.

B: Codes Not a Good Place

Code	Response
	Correct Response
10	Mentions the possibility of flooding, or that the soil will be too wet.
11	Mentions the possibility of wind or water erosion.
19	Other correct: *Examples They might not get a lot of sunlight.* *The farmer would have to climb the hills to sell or trade his meat, vegetables, or fruit.* *It might be in the rain shadow of one of the mountains or hills.*
	Incorrect Response
70	Mentions that it is an undesirable place to live: boring/lonesome/ugly... *Example: Too far from the city.*
71	Does not address the issue of farming. *Example: The river is dangerous [for children].*
72	Refers to problems due to surrounding mountains. *Examples: Avalanches (snow or rocks) from the mountains.* *Goats get lost in the mountains.*
73	Refers to sediment, soil, being rocky and negative.
76	Merely repeats information in stem.
79	Other incorrect.
	Nonresponse
90	Crossed out/erased, illegible, or impossible to interpret.
99	BLANK

Released
Advanced Mathematics Items
Population 3

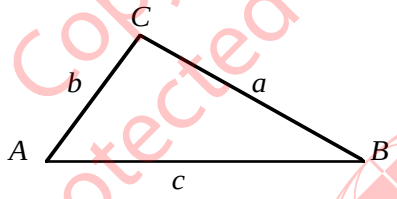
TIMSS

MATHEMATICS NOTATION

Vector: $\vec{r}$ or $\vec{AB}$ Magnitude of vector: r or $|\vec{r}|$

SELECTED MATHEMATICS FORMULAE

Triangles



$$c^2 = a^2 + b^2 - 2ab\cos C$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$\sin(A+B) = \sin A\ \cos B + \cos A\ \sin B$$

$$\cos(A+B) = \cos A\ \cos B - \sin A\ \sin B$$

Logarithms

If $a>0$, $b>0$ and $b\neq 1$, $c>0$ and $c\neq 1$

$$\log_b a = \frac{\log_c a}{\log_c b}$$

Sequences

If t_n is the general term of the arithmetic sequence with first term a and with constant difference d, then:

$$t_n = a + (n-1)d$$

If S_n is the sum of the first n consecutive terms of an arithmetic sequence with first term t_1, then:

$$S_n = \frac{n(t_1 + t_n)}{2}$$

If t_n is the general term of the geometrical sequence with first term a and with constant ratio r, then $t_n = ar^{n-1}$

If S_n is the sum of the first n consecutive terms of a geometrical sequence with first term a and with constant ratio r, where $-1 < r < 1$, then:

$$\lim_{n\to+\infty} S_n = \frac{a}{1-r}$$

If $z = x + iy = r(\cos A + i\sin A)$, $(x,y) \in R^2$ then: $z^n = [r(\cos A + i\sin A)]^n$

$= r^n(\cos nA + i\sin nA)$

(Continued on the next page.)

SELECTED MATHEMATICS FORMULAE
(Continued)

Length, Area, and Volume.

If d is the distance between (x_1, y_1) and (x_2, y_2),

$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

$A_{cylinder(curved\ surface)} = 2\pi rh$

$V_{cylinder} = \pi r^2 h$

$V_{cone} = \frac{\pi r^2 h}{3}$

Probability

$P(A \cup B) = P(A) + P(B) - P(A \cap B)$

If $B \neq \emptyset$, $P(A \mid B) = \frac{P(A \cap B)}{P(B)}$

If A and B are independent, then

$P(A \cap B) = P(A)P(B)$

K1. If $xy = 1$ and x is greater than 0, which of the following statements is true?

A. When x is greater than 1, y is negative.

B. When x is greater than 1, y is greater than 1.

C. When x is less than 1, y is less than 1.

D. As x increases, y increases.

E. As x increases, y decreases.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	E	Numbers, Equations and Functions	Complex Procedures	85%	353

K2. In how many ways can one arrange on a bookshelf 5 thick books, 4 medium sized books and 3 thin books so that the books of the same size remain together?

A. $5!\ 4!\ 3!\ 3! = 103\ 680$

B. $5!\ 4!\ 3! = 17\ 280$

C. $(5!\ 4!\ 3!) \times 3 = 51\ 840$

D. $5 \times 4 \times 3 \times 3 = 180$

E. $2^{12} \times 3 = 12\ 288$

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	A	Numbers, Equations and Functions	Solving Problems	27%	703

K3. The acceleration of an object moving in a straight line can be determined from

A. the slope of the distance-time graph

B. the area below the distance-time graph

C. the slope of the velocity-time graph

D. the area below the velocity-time graph

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	C	Calculus	Knowing	65%	489

K4. The value of $\lim_{h \to 0} \frac{\sqrt{2+h} - \sqrt{2}}{h}$ is

A. 0

B. $\frac{1}{2\sqrt{2}}$

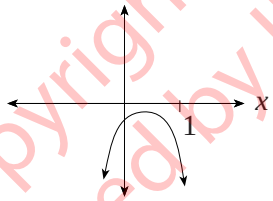
C. $\frac{1}{2}$

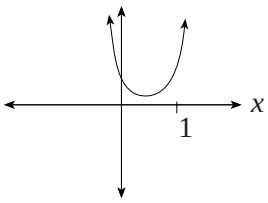
D. $\frac{1}{\sqrt{2}}$

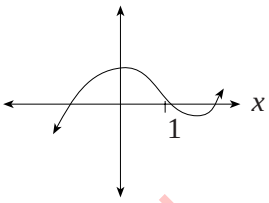
E. ∞

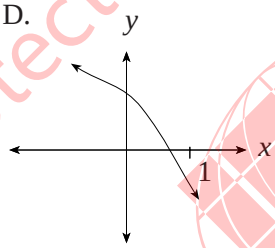
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	B	Calculus	Routine Procedures	29%	692

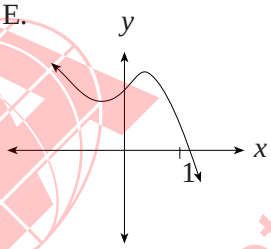
K5. Which of the following graphs has these features:
$f'(0) > 0$, $f'(1) < 0$, and $f''(x)$ is always negative?

A.


B.


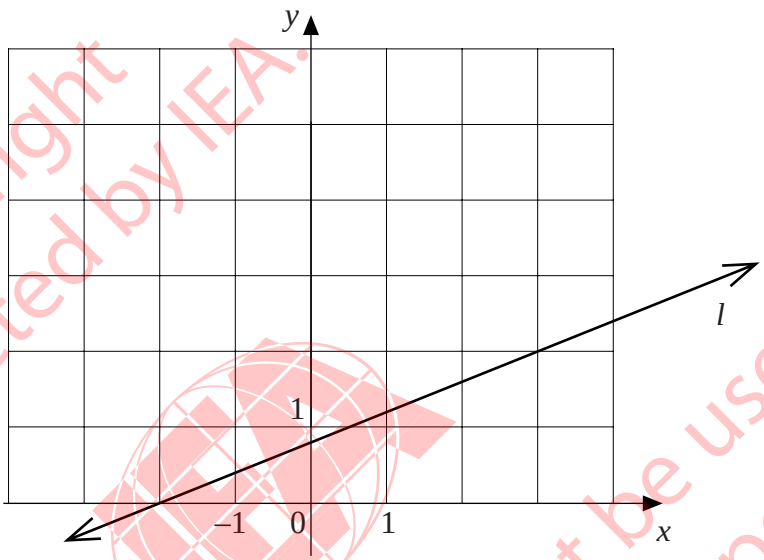
C.


D.


E.


Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	A	Calculus	Solving Problems	45%	601

K6. The line l in the figure is the graph of $y = f(x)$.



$\int_{-2}^{3} f(x)\,dx$ is equal to

A. 3

B. 4

C. 4.5

D. 5

E. 5.5

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	D	Calculus	Routine Procedures	58%	537

K7. The vertices of the triangle PQR are the points P(1, 2), Q(4, 6) and R(– 4, 12). Which one of the following statements about triangle PQR is true?

A. PQR is a right triangle with the right angle $\angle$P.

B. PQR is a right triangle with the right angle $\angle$Q.

C. PQR is a right triangle with the right angle $\angle$R.

D. PQR is not a right triangle.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	B	Geometry	Routine Procedures	56%	547

K8. Which one of the following conics is represented by the equation $(x - 3y)(x + 3y) = 36$?

A. Circle

B. Ellipse

C. Parabola

D. Hyperbola

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	D	Geometry	Knowing	28%	690

K9. Determine the distance between the x-intercept and z-intercept of the plane whose equation is $3x + 2y - 4z = 12$.

A. $\sqrt{7}$

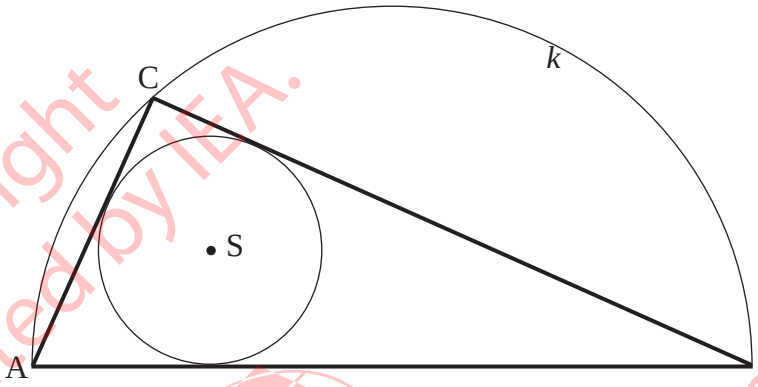
B. 1

C. 5

D. 7

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	C	Geometry	Routine Procedures	43%	613

K10.



AB is the diameter of a semicircle *k*, C is an arbitrary point on the semicircle (other than A or B), and S is the centre of the circle inscribed into Δ ABC.

Then the measure of

A. ∠ASB changes as C moves on *k*.

B. ∠ASB is the same for all positions of C but it cannot be determined without knowing the radius.

C. ∠ASB = 135° for all C.

D. ∠ASB = 150° for all C.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	C	Geometry	Solving Problems	21%	741

K11. A set of 24 cards is numbered with the positive integers from 1 to 24. If the cards are shuffled and if only one is selected at random, what is the probability that the number on the card is divisible by 4 or 6?

A. $\frac{1}{6}$

B. $\frac{5}{24}$

C. $\frac{1}{4}$

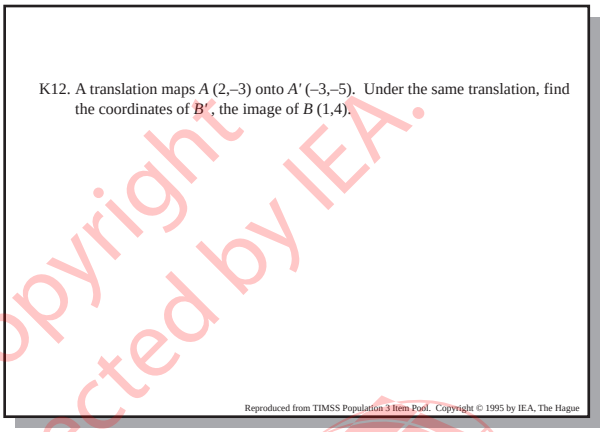
D. $\frac{1}{3}$

E. $\frac{5}{12}$

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	D	Probability & Statistics	Routine Procedures	50%	578

K12. A translation maps A (2,–3) onto A' (–3,–5). Under the same translation, find the coordinates of B', the image of B (1,4).

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Geometry	Routine Procedures	52%	570

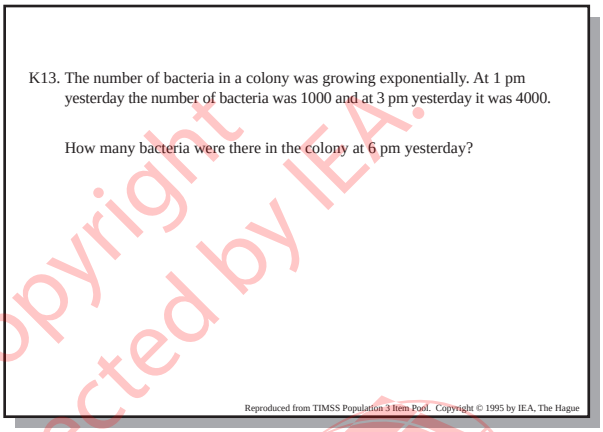


Code	Response
	Correct Response
10	(-4, 2). No work shown, or only points are shown in a diagram such that method cannot be determined.
11	(-4, 2). Method: A diagram that shows more than points is drawn showing the geometrical method used such as mid-point, slope, or change in x- and y-direction.
12	(-4, 2). Method: The coordinates of the translation vector are (-5, -2); the translation vector (-5, -2) is added to B (1,4) to obtain B' (-4, 2). **Note:** If diagram is shown and the translation vector is indicated, also use code 12.
19	Other correct responses with method are shown.
	Incorrect Response
70	Response incorrect. No work shown.
71	(6, 6). Method as in code 12 but uses incorrect translation vector, (5, 2).
72	Method as in code 12 with correct translation vectors (-5, -2) but with error in subtraction of negative numbers.
73	Method as in code 11 with an understandable diagram consisting of more than just points. At least one coordinate of B' is incorrect.
79	Other incorrect responses with method shown. (If no method/work shown, code 70.)
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

K13. The number of bacteria in a colony was growing exponentially. At 1 pm yesterday the number of bacteria was 1000 and at 3 pm yesterday it was 4000.

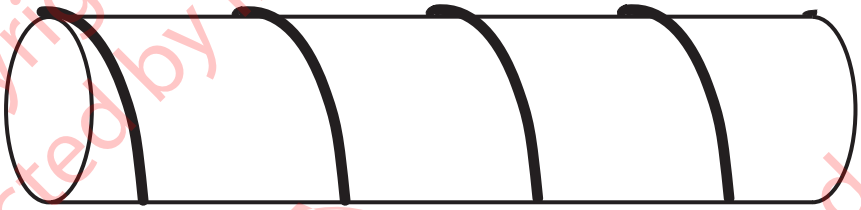
How many bacteria were there in the colony at 6 pm yesterday?

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Numbers, Equations and Functions	Solving Problems	27%	710



Code	Response
	Correct Response
10	32 000. No work shown.
11	32 000. States explicitly that the number of bacteria doubles every hour or shows sequence (pattern) of numbers of bacteria in 1 hour intervals: 1 000, 2 000, 4 000, 8 000, 16 000, 32 000.
12	32 000. States that the numbers form a geometric series with common ratio r = 2 OR uses $S_n = ar^{n-1}$ for r = 2 OR uses an exponential equation in the general form of $y = A(a^k)$ with A = 1000, a = 2, and K = 5.
13	32 000. Uses an exponential equation involving e such as $y = 1000\ (e^{kt})$, k = 0.6931, t = 5.
19	Other correct responses.
	Incorrect Response
70	Answers other than 16 000 and 64 000. No work shown.
71	16 000 or 64 000. Exponential equation or pattern has been recognized correctly but there is a numerical error.
72	Responses other than 16 000 and 64 000 where a correct exponential has been used but there is a numerical or algebraic error. *Examples:* $s_n = ar^{n-1}$ $y = A\ (a^k)$
73	Responses where the exponential function of the form $y = A(e^x)$ has been used but a numerical or algebraic error is made.
79	Other incorrect responses.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

K14. A string is wound symmetrically around a circular rod. The string goes exactly 4 times around the rod. The circumference of the rod is 4 cm and its length is 12 cm.



Find the length of the string. Show all your work.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Geometry	Solving Problems	10%	752

K14. A string is wound symmetrically around a circular rod. The string goes exactly 4 times around the rod. The circumference of the rod is 4 cm and its length is 12 cm.

Find the length of the string. Show all your work.

Code	Response
	Correct Response
20	Length of string = 20 cm. Method: • The surface of the rod is represented as a rectangle 4 cm by 12 cm. • Four parallel congruent segments are drawn in the rectangle indicating the position of the string. • Length of one segment is calculated using Pythagorean theorem $\sqrt{3^2 + 4^2} = 5$. Total length of string = 4 x 5 cm = 20 cm.
21	Length of string = 20 cm. Method: • Half of surface of rod represented as rectangle 2 cm by 12 cm. • Eight congruent segments drawn in the rectangle indicating position of string. • Length of one segment calculated using Pythagorean theorem $\sqrt{2^2 + 1.5^2} = 2.5$. Total length of string = 8 x 2.5 cm = 20 cm.
22	Length of string = 20 cm. Method used: • Situation represented either by rectangle 16 x 12 with string as its diagonal OR by right triangle with sides 16 and 12 and string as its hypotenuse. Pythagorean theorem used to calculate length of string $\sqrt{16^2 + 12^2} = 20$ cm.
29	All other fully correct solutions.
	Partial Response
10	Length of string = 20 cm. No work shown.
11	Surface of rod represented by rectangle with correct dimensions and position of string correctly indicated, but numerical error in the calculation of the length of string.
19	All other partially correct solutions with correct method and minor error.

Continued Next Page

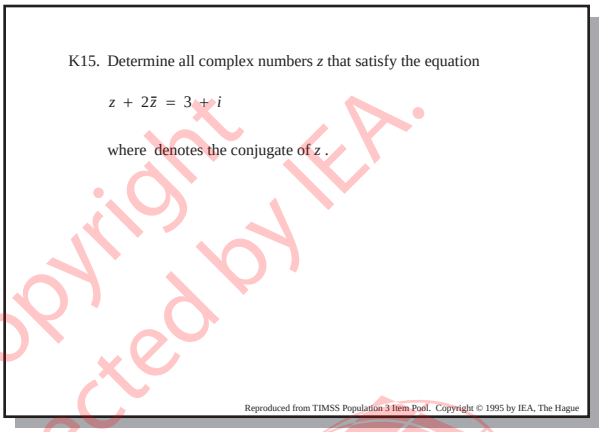
	Incorrect Response
70	Incorrect answer. No work shown.
71	Length of string = 16 cm. Argument: It is the same as 4 circles.
72	Length of string = 28 cm. Argument: "If the string were wound 4 times around the same place, its length would be 4 x 4. But since it "moves" along the rod which is 12 cm long, we must add these 12 cm to the length of the string."
73	Estimation methods: Length of 1 revolution estimated or stated but not calculated; then it is multiplied by 4. *Examples: 1 revolution is approx. 6 cm long, length of string is 4 x 6 = 24 cm.* *1 revolution is (4 + 1.5) cm long, length of string is 4 x 5.5 = 22 cm.* *Length of string must be greater than 16 cm (it would be 16 cm if it were 4 circles) and/or* *Length of string must be less than 16 + 12 = 28 cm.* *16 cm < L < 28 cm)*
74	String is represented by a curve, e.g. parts of a circle or an ellipse.
79	All other incorrect attempts with some work shown.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

K15. Determine all complex numbers z that satisfy the equation

$$z + 2\bar{z} = 3 + i$$

where $\bar{z}$ denotes the conjugate of z .

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Numbers, Equations and Functions	Routine Procedures	17%	696



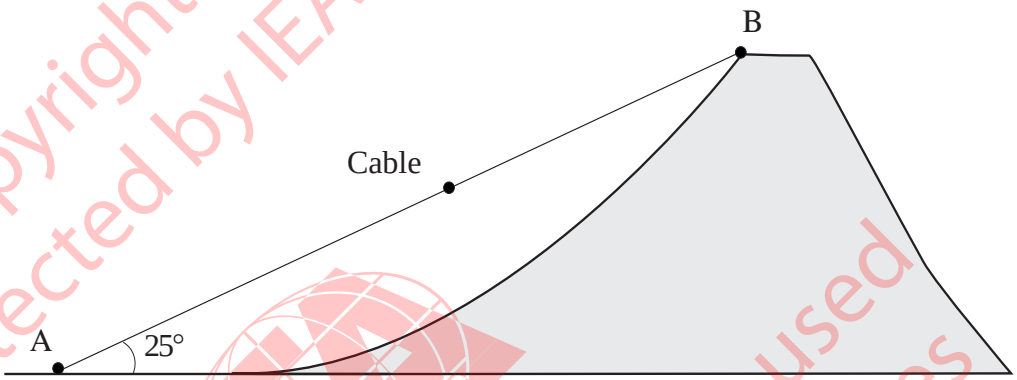
K15. Determine all complex numbers z that satisfy the equation

$$z + 2\bar{z} = 3 + i$$

where $\bar{z}$ denotes the conjugate of z.

Code	Response
	Correct Response
20	z = 1 - i. No work shown
21	z = 1 - i. Method: Let z = a + bi. The given equation is then equivalent to 3a - ib = 3 + i OR 3(a-1) - i (b + 1) = 0. This equation correctly solved, finding a = 1, b = -1.
29	z = 1 - i, obtained by any other correct method.
	Partial Response
10	Equation for a,b is derived correctly, but either left unsolved or solution contains numerical or single algebraic error.
11	Due to numerical error an incorrect equation for a,b has been derived and solved, either correctly or incorrectly.
19	Other partially correct solutions with correct method but contains a numerical or single algebraic error.
	Incorrect Response
70	Incorrect answer. No work shown.
71	Attempts using b - ai as the conjugate of z, which leads to z = -3 - i.
72	Attempts using -z as the conjugate of z which leads to z = -1/3 + 5/3i.
73	Attempts using 1/z as the conjugate of z.
79	Other incorrect responses.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret
99	BLANK

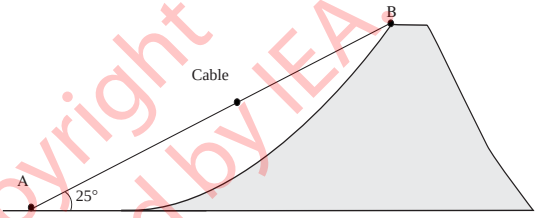
K16. The ride with the cable car from station A to station B at the top of Mt. Glacier takes 16 minutes. The average speed of the cable car is 2 meters per second and it moves in a straight line forming a 25° angle with the horizontal.



Find the height of Mt. Glacier (measured from the level of station A) to the nearest meter. Show all your work.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Numbers, Equations and Functions	Solving Problems	33%	631

K16. The ride with the cable car from station A to station B at the top of Mt. Glacier takes 16 minutes. The average speed of the cable car is 2 meters per second and it moves in a straight line forming a 25° angle with the horizontal.



Find the height of Mt. Glacier (measured from the level of station A) to the nearest meter. Show all your work.

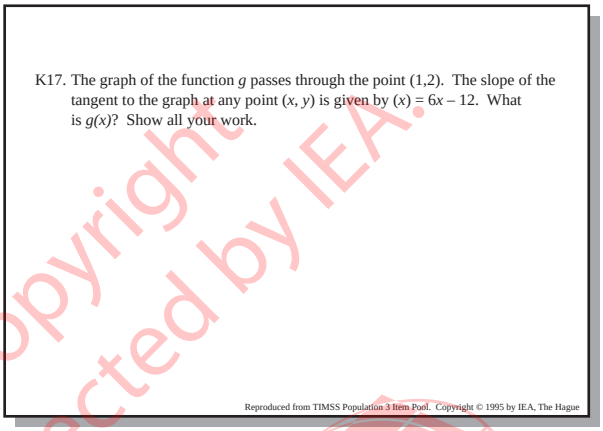
Code	Response
	Correct Response
30	811 m or 0.811 km. Method: AB = 16 x 60 s(2m/s) = 1920m; height = 1920 sin 25^{o} m = 8.114270625 m. Then rounds correctly to 811 m, or 0.811 km.
31	811 m or 0.811 km. Method: First AB calculated, then cos 25^{o} used to determine AC and then the Pythagorean theorem used to find CB as $\sqrt{AB^2 - AC^2}$. **Note**: C denotes the point vertically beneath station B at the level of A. Height = $\sqrt{(1920)^2 - (1920 Cos 25°)^2}$ = 811.4270625 m. Then rounds correctly to 811 m, or 0.811 km.
39	Other complete correct responses.
	Partial Response
20	As code 30, but numerical result is not rounded.
21	1920 sin 25^{o}as in code 30, but numerical value of expression is either not given or is calculated incorrectly.
22	As code 31, but numerical result is not rounded correctly.
23	Distance AB calculated incorrectly due to wrong method and/or numerical error in code 30 or code 31; the rest is correct.
24	As code 31, but value given is incorrect due to numerical error(s), other than in calculation of AB (code 21).
29	Other nearly complete solutions with a numerical error.

Continued Next Page

	Minimal Response
10	Distance AB found to be 1920 m, height calculated as 1920/sin 25 (leads to 4543 m) or 1920.cos 25 (leads to 1740 m) or 1920.tg 25 (leads to 895m). Numerical answer is given correctly or incorrectly or is not given at all.
11	Distance AB found to be 1920 m. Other work incorrect EXCEPT as stated in code 10 or impossible to interpret.
19	Other minimally correct solutions with not more than a total of two algebraic or trigonometric errors.
	Incorrect Response
70	Distance AB incorrectly calculated and wrong method(s) used to find height.
79	Other incorrect attempts.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

K17. The graph of the function g passes through the point (1,2). The slope of the tangent to the graph at any point (x, y) is given by $g'(x) = 6x - 12$. What is $g(x)$? Show all your work.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Calculus	Solving Problems	28%	642

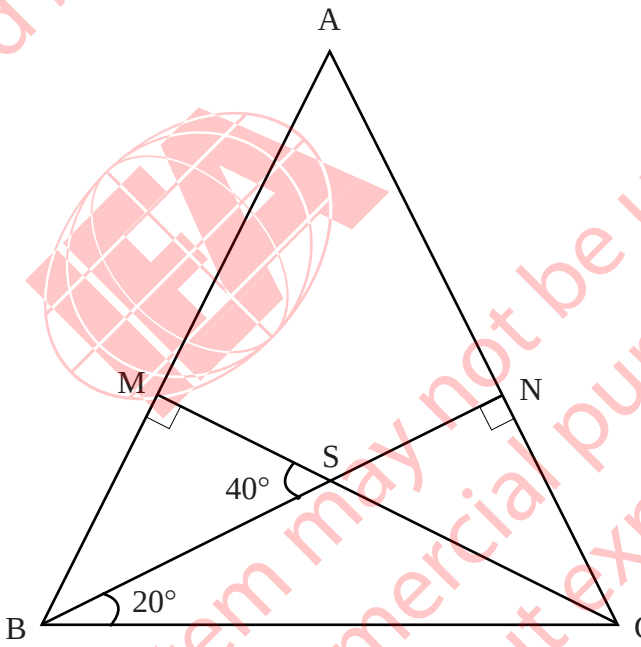


Code	Response
	Correct Response
30	g(x) = $3x^2$ - 12x + 11. Method: First the function *g* is determined to be of the form g(x) = $3x^2$ - 12 x + c. Then c is found to be 11 by solving the equation g(1) = 2, i.e. 3 - 12 + c = 2.
39	g(x) = $3x^2$ - 12x + 11. Other correct method used.
	Partial Response
20	g(x) = $3x^2$ - 12 x + 11. No work shown.
21	Answer of the form g(x) = 3 x^2 - 12 x + c, where c is a numerical value other than 11. Method correct; the value of c given incorrectly due to error in solving the equation g(1) = 2. If c = 13, check to determine if 13 results from an error in solving g(1) = 2[code 21] or from solving correctly the "reversed" equation, g(2) = 1 [code 22].
22	Method: Solves the "reversed" equation g(2) = 1 and determines the value of c to be 13. If an error is made in solving the reversed equation; c determined to be a number other than 13, use code 11.
23	Answers of the form g(x) = $3x^2$ -12x + c, where the value of c is NOT determined by solving either g(1) = 2 or g(2) = 1.
29	Other nearly complete solutions with a minor error.
	Minimal Response
10	Answer of the form g(x) = $3x^2$ - 12 x + c, where a numerical value of c is NOT found.
11	Method: Incorrectly solves "reversed" equation g(2) = 1, finds c to be a number other than 13.
19	Other minimally correct solutions
	Incorrect Response
70	g(x) = $3x^2$ - 12x and no work shown.
71	Answers of the form g(x) = $6x^2$ - ... or other integration error.
79	Other incorrect attempts.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

K18. In the ΔABC the altitudes BN and CM intersect at point S. The measure of $\angle MSB$ is 40° and the measure of $\angle SBC$ is 20°. Write a PROOF of the following statement:

"ΔABC is isosceles."

Give geometric reasons for statements in your proof.

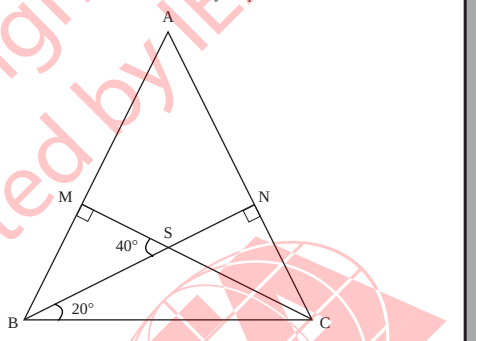


Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Geometry	Justifying and Proving	34%	626

K18. In the ΔABC the altitudes BN and CM intersect at point S. The measure of ∠MSB is 40° and the measure of ∠SBC is 20°. Write a PROOF of the following statement:

"ΔABC is isosceles."

Give geometric reasons for statements in your proof.



Note: To be considered correct, all responses must include mention of all geometric facts used, all calculations made, and a conclusion

Code	Response
	Correct Response
20	Correct proof. Proves that ∠B = ∠ C using the following facts: • the sum of angles in any triangle is 180^{o}. • if two angles of a triangle are equal, the triangle is isosceles. and possibly also uses: • vertically opposite angles are equal. • supplementary angles add to 180^{o}. The concept of congruence is not used.
21	As code 20 but somewhere in the proof uses the fact that some triangles: e.g. triangles BCM and CBN, OR triangles BMS and CNS, are congruent.
29	All other fully correct and complete proofs.
	Partial Response
10	As in codes 20-21 shows ∠B and ∠C are equal giving steps in logical order, but omits one step or one reason or gives one incorrect reason.
11	As in codes 20-21 shows ∠B and ∠C are equal, states correct geometric facts but not in a logically correct order.
19	Other responses with minor errors.
	Incorrect Response
70	Shows measures of angles correctly on figure but no geometric facts mentioned or argumentation given.
71	Incorrect argumentation and/or includes more than one incorrect geometric fact, step, or reason.
72	"Proof" is circular; makes use of statements which are equivalent to what is to be proven.
79	Other incorrect responses.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

L1. What are all values of x for which the inequality $5x + \frac{5}{3} \leq -2x - \frac{2}{3}$ is true?

A. $x \leq -\frac{7}{9}$

B. $x \leq -\frac{1}{3}$

C. $x \geq 0$

D. $x \geq \frac{7}{3}$

E. $x \geq \frac{9}{3}$

L-1

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	B	Numbers, Equations and Functions	Routine Procedures	73%	444

L2. Given $\log_b 2 = \frac{1}{3}$, $\log_b 32$ is equal to

A. 2

B. 5

C. $-\frac{3}{5}$

D. $\frac{5}{3}$

E. $\frac{3}{\log_2 32}$

L-2

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	D	Numbers, Equations and Functions	Routine Procedures	63%	505

L3. A radio-active element decomposes according to the formula,

$$y = y_o e^{-kt}$$

where y is the mass of the element remaining after t days and y_o is the value of y for $t = 0$.

Find the value of the constant k for an element whose half-life (i.e. time to decompose half of the material) is 4 days.

A. $\frac{1}{4}\log_e 2$

B. $\log_e \frac{1}{2}$

C. $\log_2 e$

D. $(\log_e 2)^{\frac{1}{4}}$

E. $2e^4$

L-3

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	A	Numbers, Equations and Functions	Complex Procedures	44%	610

L4. An examination consists of 13 questions. A student must answer only one of the first two questions and only nine of the remaining ones. How many choices of questions does the student have?

A. $^{13}C_{10} = 286$

B. $^{11}C_{8} = 165$

C. $2 \times {}^{11}C_{9} = 110$

D. $2 \times {}^{11}P_{2} = 220$

E. some other number

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	C	Numbers, Equations and Functions	Solving Problems	48%	582

L5. The sum of the infinite geometric series $1-\frac{1}{2}+\frac{1}{4}-\frac{1}{8}+...$ is

A. $\frac{5}{8}$

B. $\frac{2}{3}$

C. $\frac{3}{5}$

D. $\frac{3}{2}$

E. ∞

L-5

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	B	Calculus	Routine Procedures	45%	597

L6. The velocity v of a body moving in a straight line t seconds after starting from rest is $v = 4t^3 - 12t^2$ meters per second.

How many seconds after starting does its acceleration become zero?

A. 1

B. 2

C. 3

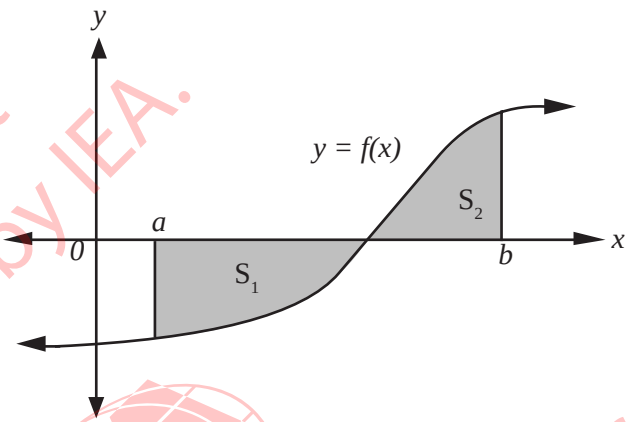
D. 4

E. 6

L-6

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	B	Calculus	Routine Procedures	33%	669

L7.



This figure shows the graph of $y = f(x)$.
S_1 is the area enclosed by the x- axis, $x = a$ and $y = f(x)$;
S_2 is the area enclosed by the x- axis, $x = b$ and $y = f(x)$;
where $a < b$ and $0 < S_2 < S_1$.

The value of $\int_a^b f(x)dx$ is

A. $S_1 + S_2$

B. $S_1 - S_2$

C. $S_2 - S_1$

D. $|S_1 - S_2|$

E. $\frac{1}{2}(S_1 + S_2)$

L-7

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	C	Calculus	Solving Problems	35%	658

L8. The rectangular coordinates of three points in a plane are $Q(-3, -1)$, $R(-2, 3)$, and $S(1, -3)$. A fourth point T is chosen so that $\overrightarrow{ST} = 2\overrightarrow{QR}$.

The y-coordinate of T is

A. –11

B. –7

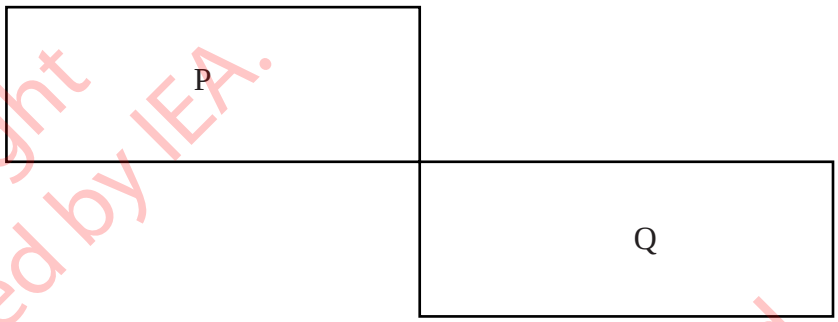
C. –1

D. 1

E. 5

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	E	Geometry	Routine Procedures	50%	576

L9.



The rectangle labeled Q CANNOT be obtained from the rectangle labeled P by means of a

A. reflection (about an axis in the plane of the page)

B. rotation (in the plane of the page)

C. translation

D. translation followed by a reflection

L-9

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	A	Geometry	Knowing	56%	546

L10. A warning system installation consists of two independent alarms having probabilities of operating in an emergency of 0.95 and 0.90 respectively. Find the probability that at least one alarm operates in an emergency.

A. 0.995

B. 0.975

C. 0.95

D. 0.90

E. 0.855

L-10

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	A	Probability & Statistics	Solving Problems	29%	691

L11. The Smith sisters made these statements. If Vera told the truth, who else must have told the truth?

Lucy: "If the rug is in the car, then it is not in the garage."
Sally: "If the rug is not in the car, then it is in the garage."
Vera: "If the rug is in the garage, then it is in the car."
Cherry: "If the rug is not in the car, then it is not in the garage."

A. Lucy

B. Sally

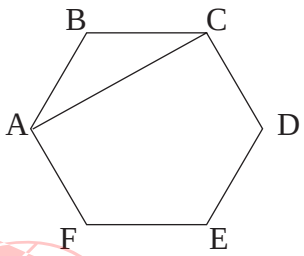
C. Cherry

D. none need have told the truth.

L-11

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	C	Validation and Structure	Routine Procedures	76%	425

L12. Each side of the regular hexagon ABCDEF is 10 cm long. What is the length of the diagonal AC?



A. $10\sqrt{3}$ cm

B. 20 cm

C. $5\sqrt{3}$ cm

D. 10 cm

E. $20\sqrt{3}$ cm

L-12

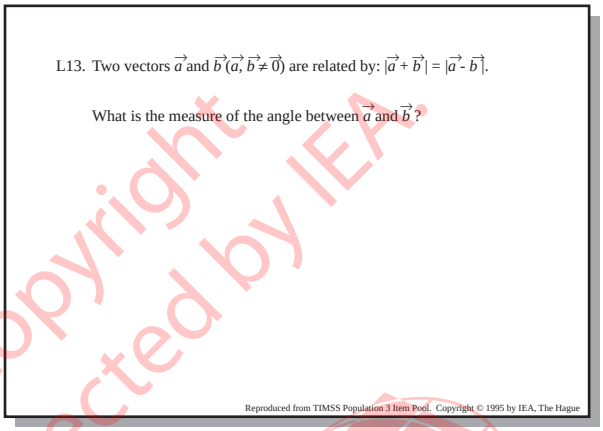
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	A	Geometry	Solving Problems	66%	486

L13. Two vectors $\vec{a}$ and $\vec{b}$ ($\vec{a}, \vec{b} \neq \vec{0}$) are related by: $|\vec{a}+\vec{b}| = |\vec{a}-\vec{b}|$.

What is the measure of the angle between $\vec{a}$ and $\vec{b}$?

L-13

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Geometry	Complex Procedures	29%	699



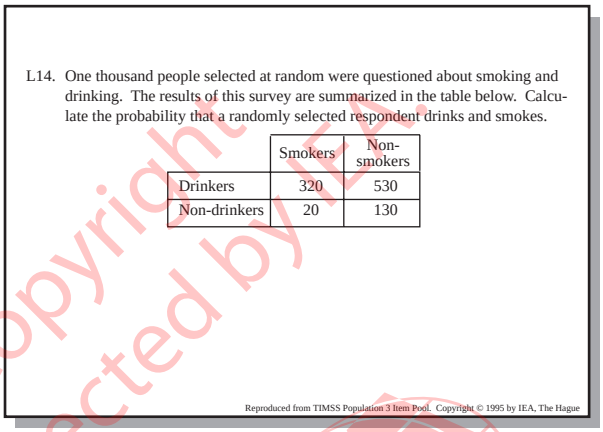
Code	Response
	Correct Response
10	90^o OR $\pm \pi/2$ OR "Given vectors are perpendicular." No work shown.
11	90^o OR $\pm \pi/2$ OR "Given vectors are perpendicular." And results derived correctly from equality given and from definition of |a|, that is, $\|a+b\| = \|a-b\| \Rightarrow |a+b|^2 = |a-b|^2 \Rightarrow (a+b)(a+b) \Rightarrow (a-b)(a-b) \Rightarrow a^2 + 2ab + b^2 = a^2 - 2ab + b^2 \Rightarrow 2ab = -2ab \Rightarrow 4ab = 0 \Rightarrow$ vectors a,b are perpendicular. **Note:** If error(s) in derivation, code 19.
12	90^o OR $\pm \pi/2$ OR "Given vectors are perpendicular." Situation is represented correctly geometrically, that is, vectors a+b and a-b represented as diagonals of a parallelogram. Conclusion stated that the given equality holds only if vectors a,b are perpendicular to each other. **Note:** If error(s) in method, code 19.
13	90^o OR $\pm \pi/2$ OR "Given vectors are perpendicular." Only presents a drawing; no explanation in words.
19	90^o OR $\pm\pi/2$ OR "Given vectors are perpendicular." Some work shown. Method may be complete and correct, or incomplete and correct, or incorrect.
	Incorrect Response
70	0^o or 180^o with or without work shown.
71	Method as in code 11, but no statement of measurement.
72	Method as in code 12, but no statement of measurement.
73	Unsuccessful atttempts to use the formula: $ab \cos \alpha = \|a\| \cdot \|b\|$.
79	All other incorrect responses.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

L14. One thousand people selected at random were questioned about smoking and drinking. The results of this survey are summarized in the table below. Calculate the probability that a randomly selected respondent drinks and smokes.

	Smokers	Non-smokers
Drinkers	320	530
Non-drinkers	20	130

L-14

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Probability & Statistics	Solving Problems	51%	570

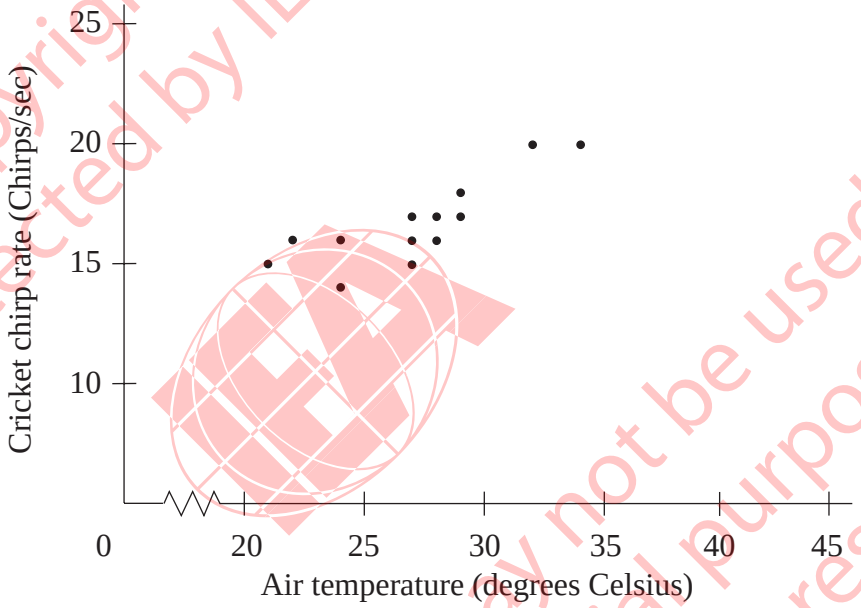


L14. One thousand people selected at random were questioned about smoking and drinking. The results of this survey are summarized in the table below. Calculate the probability that a randomly selected respondent drinks and smokes.

	Smokers	Non-smokers
Drinkers	320	530
Non-drinkers	20	130

Code	Response
	Correct Response
10	0.32 or any numerical equivalent such as $\frac{320}{1000}$ or 32%. If probability is correct, disregard rounding errors.
	Incorrect Responses
70	0.032 or similar answers involving place value error.
71	320
72	850/1000 or 340/1000
73	1/320 or 1000/320
79	Other incorrect responses.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

L15. Scientists have observed that crickets move their wings faster in warm temperatures than in cold temperatures. By noting the pitch of cricket chirps, it is possible to estimate the air temperature. Below is a graph showing 13 observations of cricket chirps per second and the associated air temperature.



a) On the graph, draw in an estimated line of best fit for these data.

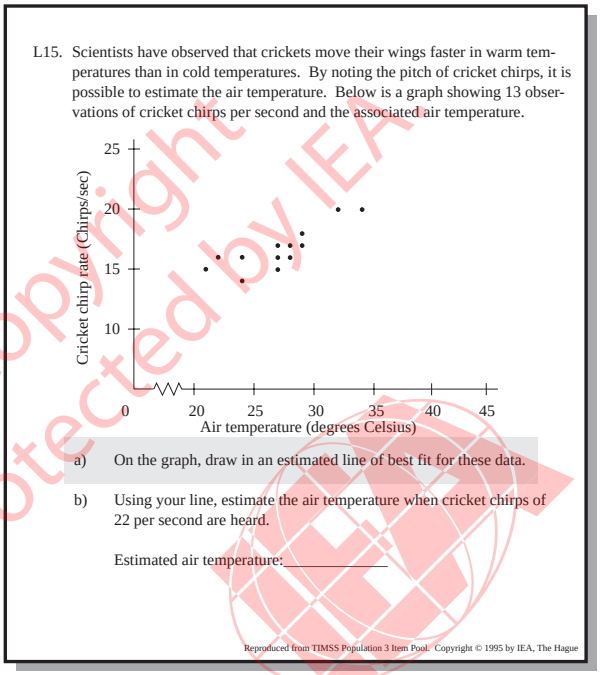
b) Using your line, estimate the air temperature when cricket chirps of 22 per second are heard.

Estimated air temperature:_____

L-15a

Part a

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Probability & Statistics	Complex Procedures	52%	570

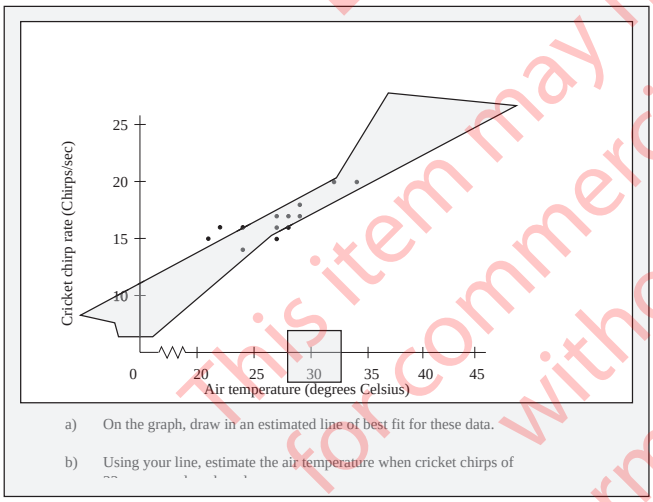


L15. Scientists have observed that crickets move their wings faster in warm temperatures than in cold temperatures. By noting the pitch of cricket chirps, it is possible to estimate the air temperature. Below is a graph showing 13 observations of cricket chirps per second and the associated air temperature.

a) On the graph, draw in an estimated line of best fit for these data.

b) Using your line, estimate the air temperature when cricket chirps of 22 per second are heard.

Estimated air temperature:_____



Example of template showing allowable range

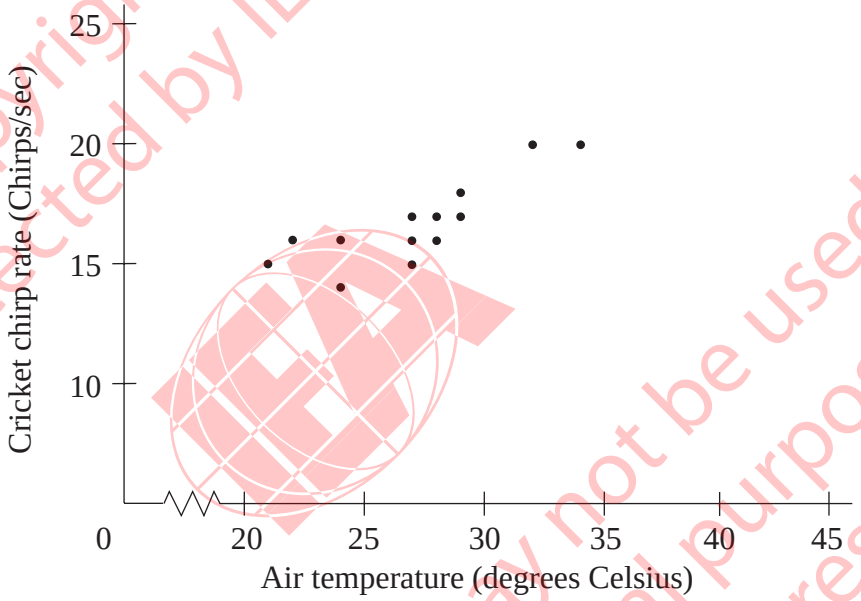
a) On the graph, draw in an estimated line of best fit for these data.

b) Using your line, estimate the air temperature when cricket chirps of

A: Codes for Line of Best Fit

Code	Response
	Correct Response
10	When template is lined up with the origin, the straight line of best fit should appear in the cut out section of the template for all air temperatures from 20 to 45 degrees Celsius.
	Incorrect Response
70	The straight line of best fit does not appear in the “cut out” section of the template for all air temperatures from 20 to 45 degrees Celsius.
71	The graph is NOT a straight line, e.g., it is a curve or zig-zag line.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

L15. Scientists have observed that crickets move their wings faster in warm temperatures than in cold temperatures. By noting the pitch of cricket chirps, it is possible to estimate the air temperature. Below is a graph showing 13 observations of cricket chirps per second and the associated air temperature.



a) On the graph, draw in an estimated line of best fit for these data.

b) Using your line, estimate the air temperature when cricket chirps of 22 per second are heard.

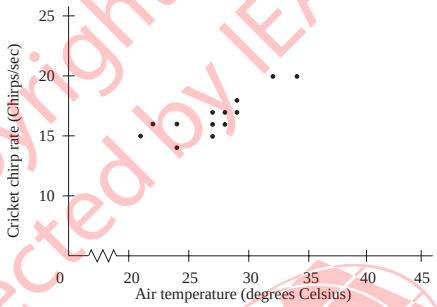
Estimated air temperature:_____

L-15b

Part b

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Probability & Statistics	Complex Procedures	64%	498

L15. Scientists have observed that crickets move their wings faster in warm temperatures than in cold temperatures. By noting the pitch of cricket chirps, it is possible to estimate the air temperature. Below is a graph showing 13 observations of cricket chirps per second and the associated air temperature.



a) On the graph, draw in an estimated line of best fit for these data.

b) Using your line, estimate the air temperature when cricket chirps of 22 per second are heard.

Estimated air temperature:_____

B: Codes for Estimate Air Temperature

Code	Response
	Correct Response
10	For code 10 in part A, the answer should appear to be a correct projection from the student's straight line of best fit and must be in the range of 34 to 42 degrees Celsius inclusive. Student's answer should be within ± 2 degrees Celsius of the correct estimate based on the student's line of best fit.
11	For code 70 in part A, the answer is not necessarily in the range of 34 to 42 degrees Celsius but should appear to be a correct projection from the student's straight line of best fit within ± 2 degrees Celsius.
	Incorrect Response
70	The answer is NOT a reasonable projection from the student's straight line of best fit.
71	The answer (estimate) is based on a curved or zig-zag line.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

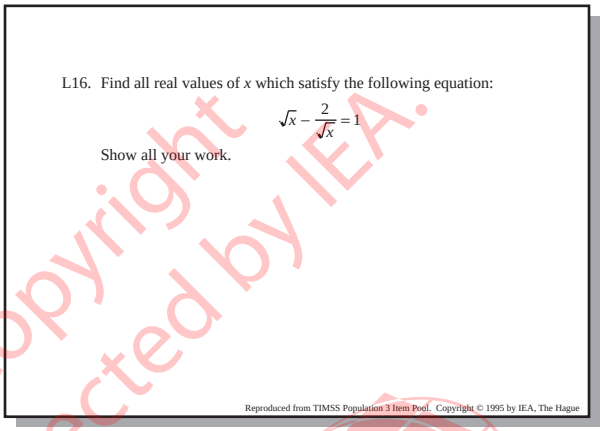
L16. Find all real values of x which satisfy the following equation:

$$\sqrt{x} - \frac{2}{\sqrt{x}} = 1$$

Show all your work.

L-16

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Numbers, Equations and Functions	Solving Problems	24%	664



L16. Find all real values of x which satisfy the following equation:

$$\sqrt{x} - \frac{2}{\sqrt{x}} = 1$$

Show all your work.

Code	Response
	Correct Response
30	x = 4. Method: 1. Original equation transformed to quadratic equation, $x^2 - 5x + 4 = 0$. 2. Two roots, x=4 and x=1 found and checked in original equation. 3. x=1 is rejected as a solution of the original equation; x=4 is accepted. **Note:** Since the original equation is squared, it is necessary to check both roots in the original equation.
31	x = 4. Method: 1. Substitution (e.g., $\sqrt{x} = a$) used and the original equation transformed, without squaring, into the quadratic equation $a^2 - a - 2 = 0$. 2. Two roots found, a = 2 and a = -1. 3. a = -1 rejected since a = -1 ≠ $\sqrt{x}$, $\sqrt{x2}$. 4. By substitution reversed.a = 2 implies $\sqrt{x} = 2$, thus x = 4. Checking in original equation is not necessary.
32	x = 4. Method: 1. Graphs $y = \sqrt{x} - \frac{2}{\sqrt{x}} - 1$ for x > 0 correctly. 2. x-coordinate of y-intercept is found to be 4. 3. Justifies that graph is increasing and thus x = 4 is an unique solution. 4. x = 4 is checked in original equation.
39	Other completely correct solutions.
	Partial Response
20	Uses code 30 to find x = 4 and x = 1 and states both are roots.
21	Uses code 31 to find a = 2 and a = -1 and then either goes no further or makes an incorrect statement such as 4 and 1 or 2 and 1 are roots of the original equation.
22	Uses code 32 showing graph, states x = 4 is a root and x = 4 is checked in the original equation.
29	Other solutions with correct overall method but with minor error(s).

Continued Next Page

Minimal Response	
10	x = 4. No work shown or some work shown, such as checking x = 4 in original equation but no argument given for why there are no other roots.
11	Solution as in codes 30 or 31: Original equation is transformed correctly into a quadratic equation, by any method, but quadratic equation either is not solved or incorrectly solved.
12	Solution as in code 22 (graphical) except that except that x = 4 is NOT checked in original equation.
19	Other minimally correct or incomplete solutions such as a simplification of the equation to $x - 2 = \sqrt{x}$.
Incorrect Response	
70	Solution as in codes 30 or 31 except original equation is transformed into an incorrect quadratic equation or to a non-quadratic equation.
79	Other incorrect responses.
Nonresponse	
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

L17. For what real value of k will the equation below describe a circle with radius 3?

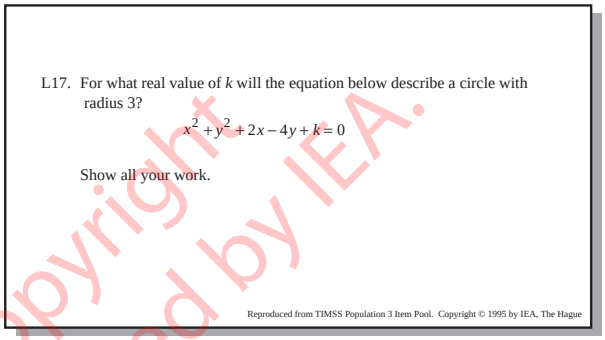
$$x^2 + y^2 + 2x - 4y + k = 0$$

Show all your work.

L-17

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Geometry	Communicating	20%	697

L-17 Coding Guide



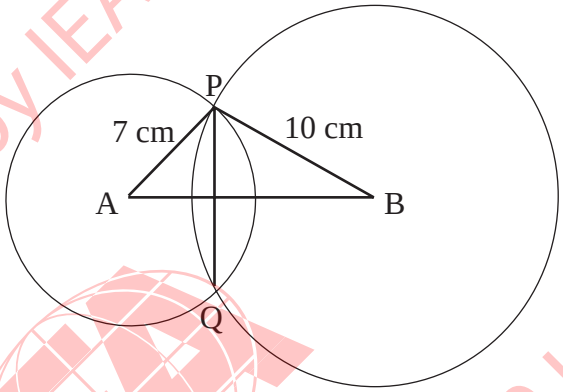
L17. For what real value of k will the equation below describe a circle with radius 3?

$$x^2 + y^2 + 2x - 4y + k = 0$$

Show all your work.

Code	Response
	Correct Response
20	K = -4. Method used: • Because of the quadratic and linear terms, the equation must be of the general form $(x+1)^2 + (y-2)^2$. From that we get the equation • $(x+1)^2 + (y-2)^2 - 5 + k = 0$ • $(x+1)^2 + (y-2)^2 = 5 - k$ • If the radius is 3, right hand side must equal 9 (= r^2) • Hence 5 - k = 9 and k = -4 is the only solution.
21	k = -4. Method used: • All circles with radius 3 have same general form: $x^2 + y^2 - 2ax - 2by + a^2 + b^2 - 9 = 0$. • From that: $2 = -2a$; $-4 = -2b$; $k = a^2+b^2 -9$; • Hence a = -1, b = 2, k = -4.
29	Any other fully correct solution.
	Partial Response
10	k = -4. No work shown.
11	Method as in code 20 but with numerical error(s) only.
12	Method as in code 21 but with numerical error(s) only.
19	All other partially correct solutions.
	Incorrect Response
70	Incorrect answer. No work shown.
71	k = -12 with or without work shown. [This answer can be obtained by the misconception that point (3,3) is on the circle, hence x = 3 and y = 3 are put into the equation.]
72	k = 3 OR k = 9 OR k = -9 with or without work shown. [This answer can be obtained by the miscoknception that the parameter k represents the radius or square of radius of the circle.]
73	k = 8 or k = 2 or k = 14 with or without work shown. [This answer can be obtained by the misconception that -5 + k = 3 OR 5 - k = 3 OR -5 + k = 9.]
79	All other incorrect responses with some work shown.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret.
99	BLANK

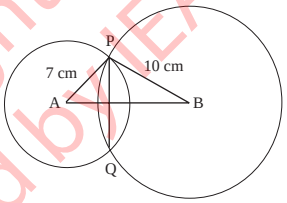
L18. Two circles with centres A and B as shown below have radii of 7 cm and 10 cm respectively. If the length of the common chord PQ is 8 cm, what is the length of AB? Show all your work.



L-18

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Advanced Mathematics	next page	Geometry	Solving Problems	50%	573

L18. Two circles with centres A and B as shown below have radii of 7 cm and 10 cm respectively. If the length of the common chord PQ is 8 cm, what is the length of AB? Show all your work.



Note: 1. Since the expected precision is not indicated, every result obtained by a correct method and reasonable and correct rounding should be accepted.
2. If student gives at some stage the correct answer but continues and later makes a numerical (not conceptual) error, ignore this error.

Code	Response
	Correct Response
20	14.9 or $\sqrt{84} + \sqrt{33}$. Method: Pythagorean theorem applied in triangles APS and BPS (S is the midpoint of PQ).
21	14.9. Method: Trigonometry functions (ratios) used correctly to determine lengths of sides of triangles OR size of angles of triangle that results in determining the length of AB. **Note:** Most frequently used trigonometric functions are sine and cosine.
29	Other complete and correct solutions.
	Partial Response
10	Method as in 20 but solution contains a (minor) error in method, or numerical or rounding error.
11	Method as in 21 but solution contains a (minor) error in method, or numerical or rounding error.
12	$\sqrt{84} + \sqrt{33}$. No work shown.
19	Other partially correct solutions, with minor error.
	Incorrect Response
70	Method: Pythagorean theorem applied to ΔAPB which is not a right triangle.
71	Incorrect use of the Pythagorean theorem in a right triangle.
72	Figure in booklet has been considered accurate and lengths of segments and/or measures of angles have been determined from the diagram.
79	All other incorrect responses.
	Nonresponse
90	Crossed-out, illegible, or impossible to interpret
99	BLANK

Released Physics Items
Population 3

TIMSS

PHYSICS NOTATION

Vectors are shown in bold italic type ***v***, ***F***, ***E***, ...

Variables and magnitudes of vectors are shown in italic type *t*, *v*, *F*, ...

SELECTED PHYSICAL CONSTANTS

acceleration due to gravity	g	$9.8\ ms^{-2}$
electron mass	m_e	9.11×10^{-31} kg
electron charge	e	1.60×10^{-19} C
proton mass	m_p	1.67×10^{-27} kg
speed of light	c	$3.0 \times 10^{8}\ ms^{-1}$
Boltzmann's constant	*k*	1.38×10^{-23} J/K
Planck's constant	*h*	6.63×10^{-34} Js
Avogadro's number	N_A	6.02×10^{23} molecules/mole
Gravitational constant	G	$6.67 \times 10^{-11}\ Nm^2kg^{-2}$
permeability constant	μ_0	$1.26 \times 10^{-6}\ Hm^{-1}$
permittivity constant	ε_0	$8.85 \times 10^{-12}\ Fm^{-1}$
universal gas constant	R	8.32 J/(mole)(K)
pressure: 1 atmosphere		$1.01 \times 10^{5}\ Nm^{-2}$

SELECTED PHYSICS FORMULAE

Mechanics

$$v = u + at$$

$$s = ut + \frac{1}{1}at^2$$

$$E_k = \frac{1}{2}mv^2$$

$$E_p = mgh$$

$$E_{spring} = \frac{1}{2}\mathrm{k}x^2$$

$$F = ma$$

$$Fdt = dp$$

$$F = \mathrm{G}\frac{m_1 m_2}{r^2}$$

$$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$

$$p = p_0 + \rho gh$$

$$dW = \boldsymbol{F} \bullet d\boldsymbol{s}$$

Heat, Kinetic Theory

$$Q = cm\Delta t = C\Delta t$$

$$\Delta Q = \Delta U + \Delta W$$

$$pV = NkT = n\mathrm{R}T$$

$$\frac{1}{2}m\bar{v}^2 = \frac{3}{2}kT$$

$$\Delta W = p\Delta V$$

Light, Waves

$$v = f\lambda = \frac{\lambda}{T}$$

$$n_1 \sin\alpha_1 = n_2 \sin\alpha_2$$

$$d\sin\alpha_{\mathrm{n}} = \mathrm{n}\lambda$$

$$\frac{1}{a} + \frac{1}{b} = \frac{1}{f}$$

Electricity and Magnetism

$$V = RI$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$P = VI = RI^2$$

$$\varepsilon = rI + RI$$

$$E = \frac{F}{q}$$

$$E_p = qV$$

$$\varepsilon = -\frac{d\phi}{dt}$$

$$\varepsilon = lvB$$

$$F = IlB\sin\alpha = qvB\sin\alpha$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

Relativity, Quantum Physics and Astrophysics

$$L = L_0\sqrt{1-\frac{v^2}{\mathrm{c}^2}}$$

$$T = \frac{T_0}{\sqrt{1-\frac{v^2}{\mathrm{c}^2}}}$$

$$E = \frac{E_0}{\sqrt{1-\frac{v^2}{\mathrm{c}^2}}}$$

$$E_0 = m_0\mathrm{c}^2$$

$$E_\nu = h\nu$$

$$p_\nu = \frac{h\nu}{\mathrm{c}} = \frac{h}{\lambda}$$

$$h\nu = W + E_k$$

$$\lambda = \frac{h}{mv}$$

$$\Delta p\Delta x \geq \frac{h}{4\pi}$$

$$E = -\frac{B}{n^2}$$

G1. Electrons enter a uniform magnetic field at an angle of 90° to the field. A magnetic force ***F*** acts on the electrons causing them to follow a circular path with radius *R*.

If the electrons enter the field at a greater speed, what happens to the magnitude of the magnetic force *F* and the radius *R*?

A. *F* decreases and *R* increases.

B. *F* increases and *R* decreases.

C. *F* increases and *R* increases.

D. Neither *F* nor *R* change.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	C	Electricity and Magnetism	Theorizing, Analyzing, and Solving Problems	41%	644

G2. When a small volume of water is boiled, a large volume of steam is produced. Why?

A. The molecules are further apart in steam than in water.

B. Water molecules expand when heated.

C. The change from water to steam causes the number of molecules to increase.

D. Atmospheric pressure works more on water molecules than on steam molecules.

E. Water molecules repel each other when heated.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	A	Heat	Theorizing, Analyzing, and Solving Problems	65%	502

G3. A jar of oxygen gas and a jar of hydrogen gas are at the same temperature.

Which of the following has the same value for the molecules of both gases?

A. the average velocity

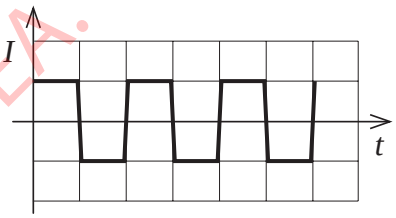
B. the average momentum

C. the average force

D. the average kinetic energy

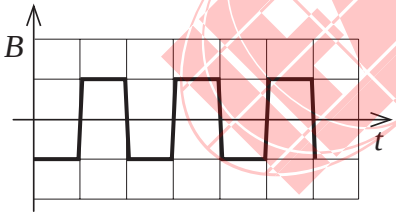
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	D	Heat	Understanding	41%	637

G4. A coil is positioned in a varying magnetic field ***B*** which causes an induced current *I* in the coil as shown in the current-time (*I*-*t*) diagram below.

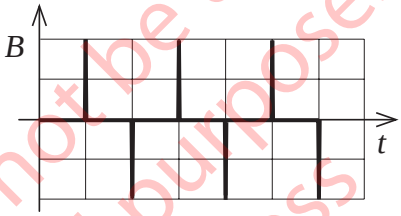


Which one of the following diagrams best represents the variation of the magnetic field?

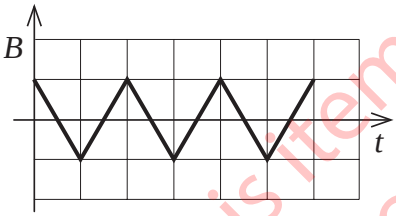
A.



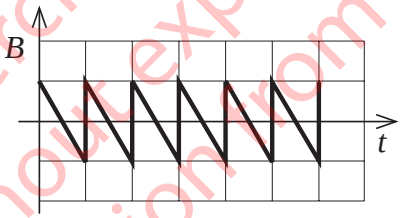
B.



C.

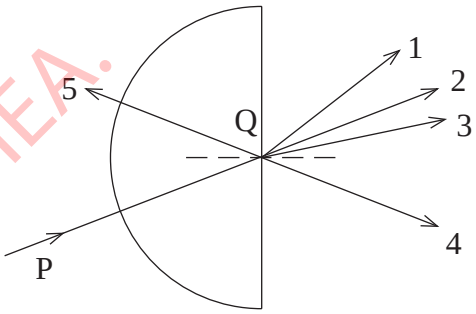


D.



Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	C	Electricity and Magnetism	Using Tools, Routine Procedures, and Science Processes	34%	682

G5. This item refers to the following diagram.



A ray of light passes from P to Q through a semicircular glass block in air.

Which arrow shows the direction in which the refracted ray of light would travel after leaving Q?

A. 1

B. 2

C. 3

D. 4

E. 5

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	A	Wave Phenomena	Theorizing, Analyzing, and Solving Problems	37%	664

G6. By what process do most stars release energy?

A. Electromagnetic induction resulting from strong magnetic fields

B. Rapid rotation of the star

C. Radioactivity in the interior of the star

D. Nuclear fusion in the interior of the star

E. Heat which was stored when the star was 'born'

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	D	Modern Physics: Particle, Quantum and Astrophysics, and Relativity	Understanding	59%	541

G7. A car manufacturer carries out a series of tests on a new model. Two cars, P and Q, of equal mass, moving at the same speed, are on a collision course as shown in Figure 1. A third car, R, of the same mass as the others and moving at the same speed, is on a collision course with an immovable wall of very high mass, as shown in Figure 2. In both cases the cars come to rest after collision.

Figure 1

Figure 2

The amount of kinetic energy transformed into energy of deformation and heat in the case of car P is

A. greater than that of car R.

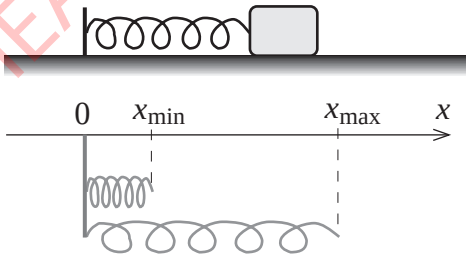
B. equal to that of car R.

C. less than that of car R.

D. not possible to answer because of insufficient information.

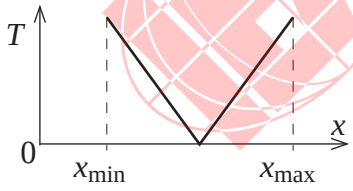
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	B	Mechanics	Theorizing, Analyzing, and Solving Problems	30%	719

G8. A block oscillates with negligible friction on the end of a spring as shown in the figure below. The minimum and maximum lengths of the spring as it oscillates are, respectively, x_{min} and x_{max}.

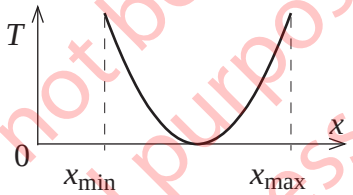


Which one of the following graphs represents the total mechanical energy (T) of the block and spring system as a function of x?

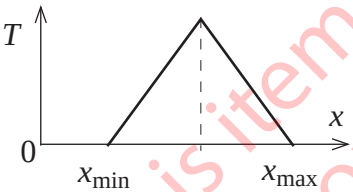
A.



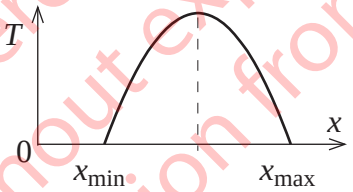
B.



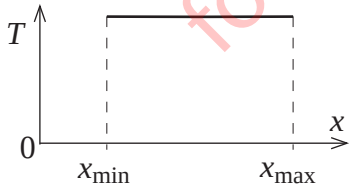
C.



D.

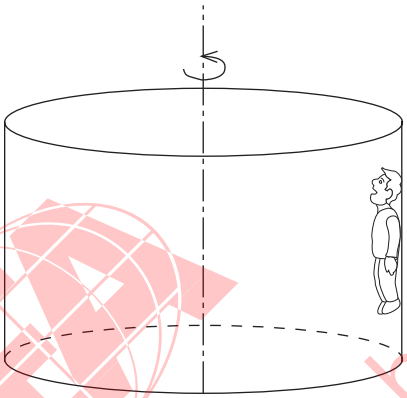


E



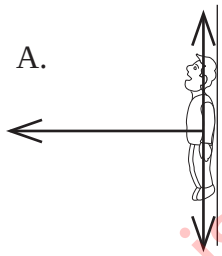
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	E	Mechanics	Using Tools, Routine Procedures, and Science Processes	36%	676

G9. The figure below shows a special sort of amusement park ride. As the ride starts to rotate about its central vertical axis the floor drops slowly but the rider does not. The rider is pressed against the rough inside wall of the rotating cylinder and remains at rest with respect to the wall. The rider's feet are not in contact with the floor.

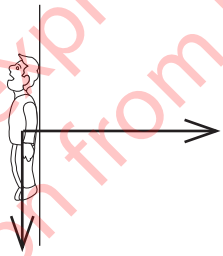


Which one of the following diagrams best represents the real forces acting on the rider?

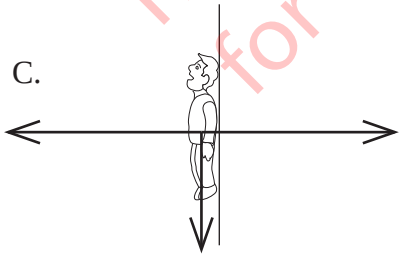
A.



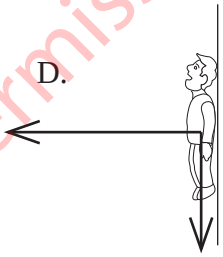
B.



C.



D.



Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	A	Mechanics	Theorizing, Analyzing, and Solving Problems	20%	802

G10. What is the minimum voltage across the electrodes of an X-ray tube which will produce X-rays with wavelength λ?

A. $\frac{hf}{\lambda}$

B. $\frac{hc}{e\lambda}$

C. $\frac{h\lambda}{ec}$

D. $\frac{h\lambda}{e}$

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	B	Modern Physics: Particle, Quantum and Astrophysics, and Relativity	Theorizing, Analyzing, and Solving Problems	32%	698

G11. The water level in a small aquarium reaches up to a mark A. After a large ice cube is dropped into the water, the cube floats and the water level rises to a new mark B.

What will happen to the water level as the ice melts? Explain your reasoning.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Heat	Theorizing, Analyzing, and Solving Problems	14%	762

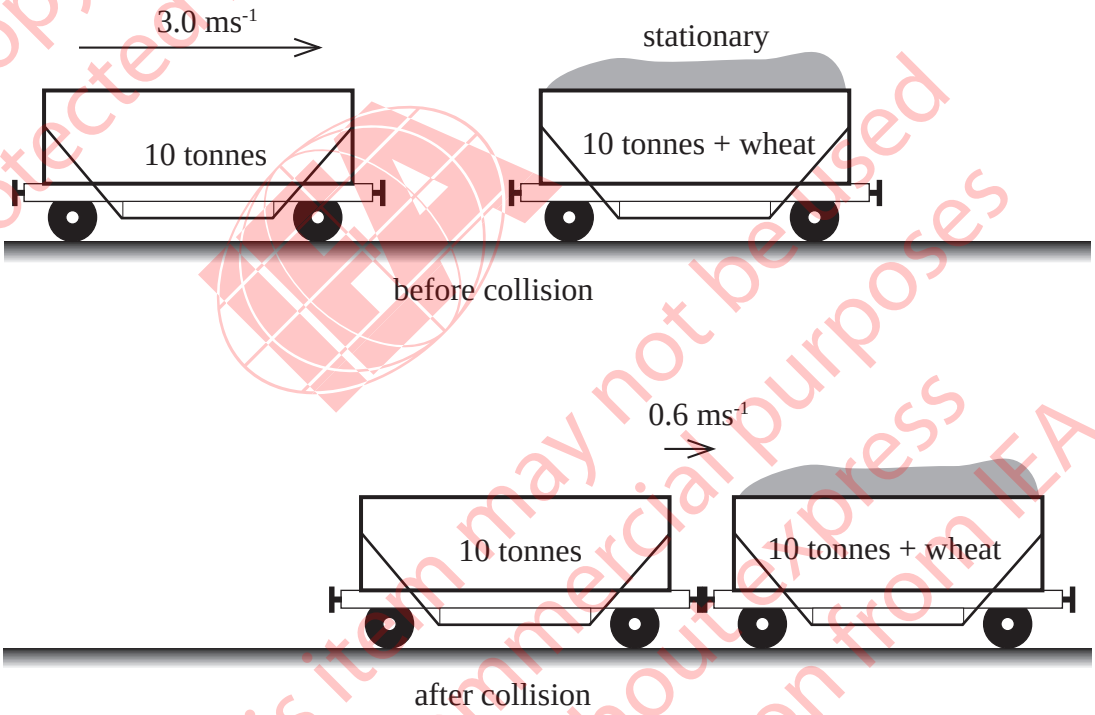
G11. The water level in a small aquarium reaches up to a mark A. After a large ice cube is dropped into the water, the cube floats and the water level rises to a new mark B.

What will happen to the water level as the ice melts? Explain your reasoning.

Code	Response
	Correct Response
20	Same level. Response refers to the fact that the volume (or mass) of the water displaced by the ice is equal to the volume (or mass) of the water produced when the ice is melted (Archimedes' principle). *Example: Level is the same because the ice displaces the same volume of water as when it melts.*
29	Other acceptable responses.
	Partial Response
10	Same level. Incomplete or incorrect explanation. *Examples: a) Ice and water has the same mass.* *b) Ice has less density than water.*
11	Same level. No explanation.
19	Other partially correct responses.
	Incorrect Response
70	Rising level, with or without explanation.
71	Sinking level. The water has smaller volume/greater density/"molecules are closer together" than the ice OR the ice has greater volume/smaller density/"molecules are further apart" than the water.
72	Sinking level. Because ice contains air.
73	Sinking level. As the ice melts the mass decreases (or disappears).
74	Sinking level. With other or without explanation.
79	Other unacceptable responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

G12. An empty railway truck of mass 10 tonne (1.0×10^4 kg) moving with a speed of 3 ms^{-1} collides with an identical stationary railway truck loaded with wheat. The two trucks couple together during the collision and then move together along the railway track with a speed of 0.6 ms^{-1}.

The situations before and after the collision are shown in the figure below.

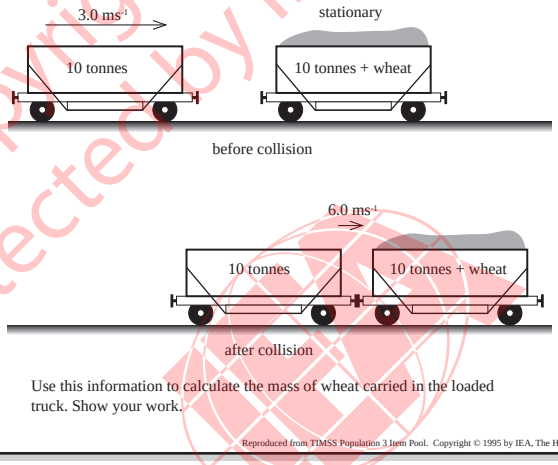


Use this information to calculate the mass of wheat carried in the loaded truck. Show your work.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Mechanics	Theorizing, Analyzing, and Solving Problems	36%	647

G12. An empty railway truck of mass 10 tonne (1.0×10^4 kg) moving with a speed of 3 ms^{-1} collides with an identical stationary railway truck loaded with wheat. The two trucks couple together during the collision and then move together along the railway track with a speed of 0.6 ms^{-1}.

The situations before and after the collision are shown in the figure below.



Use this information to calculate the mass of wheat carried in the loaded truck. Show your work.

Code	Response
	Correct Response
20	m = 30 tonnes, using the law of conservation of momentum. *Example:* $\sum mv$ *(before)* = $\sum mv$ *(after)* $m_1 v_1 = (m_1 + m_2 + x)\, v_2$ *(10t) (3.0m/s) = (20t + x) (0.6 m/s)* *x = 30t*
	Partial Response
10	As code 20, but missing or wrong units.
11	m = 30 tonnes. No work shown.
12	m = 40 tonnes; the mass of the truck is not taken into account, but conservation of momentum is correctly stated.
13	Conservation of momentum is correctly stated; calculation error.
14	Conservation of momentum is correctly stated, but no value for mass calculated.
19	Other partially correct responses.
	Incorrect Response
70	Incorrect approach, using the principle of conservation of energy.
79	Other unacceptable responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

G13. A car moving at constant speed with a siren sounding comes towards you and then passes by.

Describe how the frequency of the sound you hear changes.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Wave Phenomena	Theorizing, Analyzing, and Solving Problems	36%	673

G13. A car moving at constant speed with a siren sounding comes towards you and then passes by.

Describe how the frequency of the sound you hear changes.

Code	Response
	Correct Response
10	Response refers to the fact that the frequency (or the pitch) is higher as the car approaches and is lower as the car moves away (compared to the frequency when the car is at rest). *Examples: a) Because of Doppler effect the frequency changes from higher to lower.* *b) The pitch is higher as the car comes closer and lower after it goes by.*
11	Refers to the fact that the change in frequency is described as change in wavelength, from becoming shorter (as car approaches) to becoming longer (as car moves away). *Example: When the car approaches, the wavelength of the sound is shorter than it is when the car moves away.*
19	Other acceptable responses.
	Incorrect Response
70	Refers to the fact that the frequency (or the pitch) is changing from lower to higher than normal.
71	Refers to the fact that the wavelength is changing from longer to shorter.
72	Only the loudness of the sound is described. *Example: At a distance the sound is faint but it gets louder until it is by you and then the sound fades away.*
73	Refers to the fact that the frequency (or the pitch or the wavelength) is continually changing as the car moves. *Example: The nearer the car comes, the higher is the frequency.*
79	Other incorrect responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

G14. Draw a diagram to show the paths of alpha particles, electrons, and gamma rays as they pass between two parallel metal high-voltage plates in a vacuum.

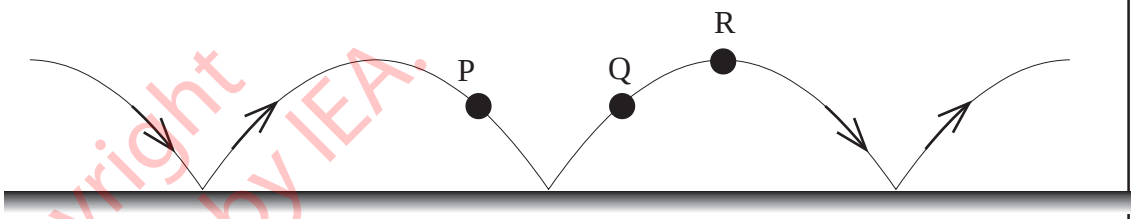
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Modern Physics: Particle, Quantum and Astrophysics, and Relativity	Understanding	27%	746

G-14 Coding Guide

G14. Draw a diagram to show the paths of alpha particles, electrons, and gamma rays as they pass between two parallel metal high-voltage plates in a vacuum.

Code	Response
	Correct Response
10	Alpha particles are deflected towards the negative plate, the electrons towards the positive plate, and the gamma rays are not deflected.
11	Alpha particles and electrons are deflected in opposite directions, gamma rays are not deflected. Charges on the plates are **not** indicated, or the plates are missing.
	Incorrect Response
70	Alpha particles and electrons are interchanged. Gamma correct.
71	Gamma rays are deflected or missing; the rest correct.
72	Electrons are deflected incorrectly or missing; the rest correct.
73	Alpha particles are deflected incorrectly or missing; the rest correct.
79	Other incorrect responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

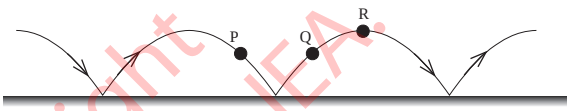
G15. The figure shows the trajectory of a ball bouncing on a floor, with negligible air resistance.



Draw arrows on the figure showing the direction of the acceleration of the ball at points P, Q and R.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Mechanics	Understanding	16%	840

G15. The figure shows the trajectory of a ball bouncing on a floor, with negligible air resistance.



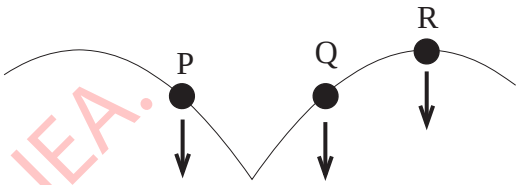
Draw arrows on the figure showing the direction of the acceleration of the ball at points P, Q and R.

Note: No explanation is required.

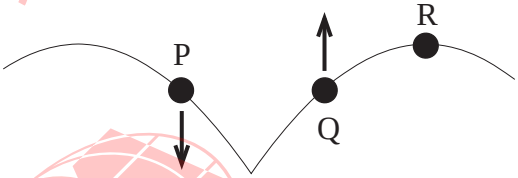
Code	Response
	Correct Response
10	The acceleration is parallel to g, downwards arrows at P, Q and R. (See following diagrams).
	Incorrect Response
70	The acceleration is parallel to g, downwards arrow at P, upwards at Q and zero at R.
71	The acceleration is parallel to g, downwards arrow at P, upwards at Q, either upwards or downwards at R.
72	The acceleration has the same direction as the motion (at least at P and Q). Any response at R.
73	The acceleration has the same direction as the motion at P, the opposite direction from the motion at Q. Any response at R.
74	The acceleration has the direction perpendicular to the motion (at least at P and Q).
79	Other incorrect responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

Continued Next Page

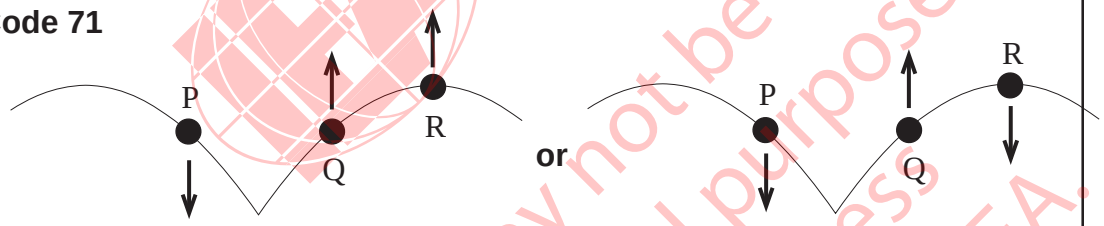
Code 10



Code 70



Code 71



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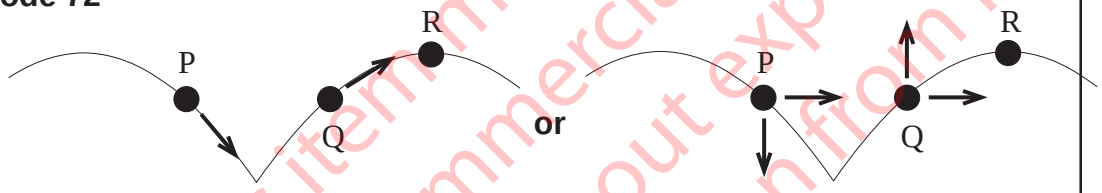
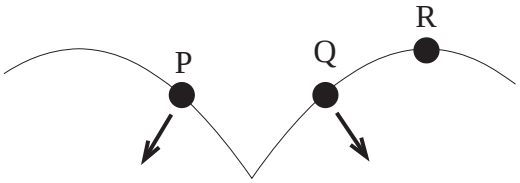
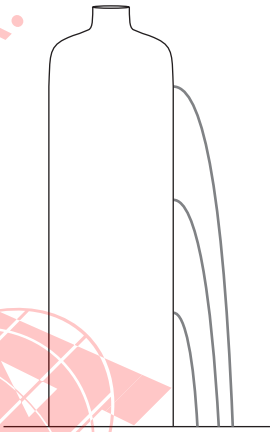


Code 73

Code 74



G16. The figure shows a common plastic bottle (1 L) filled with water and with three holes in it, so that the water runs out of the holes.



Explain what is wrong with the figure.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Mechanics	Theorizing, Analyzing, and Solving Problems	9%	899

G16. The figure shows a common plastic bottle (1 L) filled with water and with three holes in it, so that the water runs out of the holes.

Explain what is wrong with the figure.

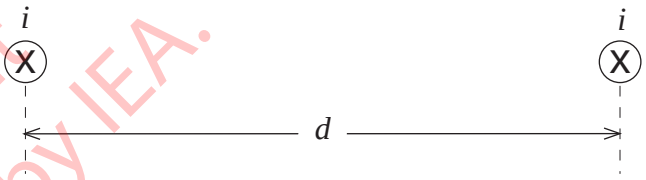
Note: A fully correct response should refer to the following:
i) The relative horizontal distances of the water from the three holes are shown incorrectly in the figure because
ii) The pressure (horizontal speed) of the water should increase with increasing depth.
A full description of the comparative horizontal distances from the three holes is not required for full credit, but if it is included, is should indicate that the water from the middle hole will actually reach the longest distance horizontally.

Code	Response
	Correct Response
20	Response refers to the fact that the pressure and/or horizontal speed of the water should increase with depth and that the horizontal distances are not correctly indicated. *Example: The pressure will increase with depth due to water above, so the water jets will have other paths.*
29	Other correct responses.
	Partial Response
10	Responses similar to Code 20, but explicitly stating that the water from the lowest hole will reach the longest distance horizontally. (Not correct. It can be shown that the water from the middle hole will reach the longest distance.) *Example: There's added pressure from water above so the water from the bottom hole will travel farther. The distance gets smaller the higher the holes are made.*
11	As code 20 but no reference to the aspect of incorrect horizontal distances. *Example: The water from the bottom holes should have greater speed than the top hole since the pressure is greater.*
19	Other partially correct responses.

Continued Next Page

Incorrect Response	
70	Refers to the fact that the water from all the three holes should reach the same distance horizontally. *Example: Gravity pulls each stream down by the same amount, so they should hit the ground in the same place.*
71	States that there is no horizontal displacement of water. *Example: The water from all 3 holes just runs down the side of the container and hits the ground in the same place.*
79	Other incorrect responses.
Nonresponse	
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

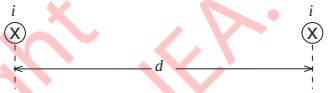
G17. The diagram shows two long parallel wires a distance d apart. Each carries a current *i* directed into the page.



Draw an arrow on the right-hand wire to show the direction of the force on it due to the current in the left-hand wire.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Electricity and Magnetism	Theorizing, Analyzing, and Solving Problems	30%	715

G17. The diagram shows two long parallel wires a distance d apart. Each carries a current *i* directed into the page.



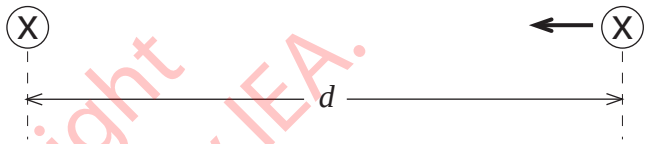
Draw an arrow on the right-hand wire to show the direction of the force on it due to the current in the left-hand wire.

Note: Apply the same codes if the arrow is drawn on the left-hand wire.

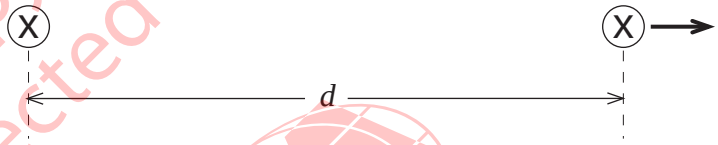
Code	Response
	Correct Response
10	Arrow showing attraction. (See following diagram).
	Incorrect Response
70	Arrow showing repulsion.
71	Arrow pointing upwards.
72	Arrow pointing downwards.
79	Other incorrect responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

Continued Next Page

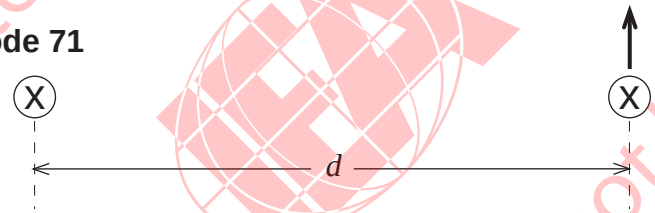
Code 10



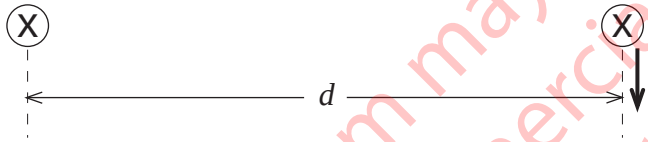
Code 70



Code 71



Code 72



G18. A stream of alpha particles is directed at a very thin sheet of gold.

Explain why most of the alpha particles pass through the sheet.

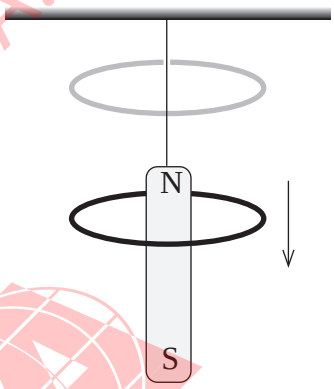
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Modern Physics: Particle, Quantum and Astrophysics, and Relativity	Theorizing, Analyzing, and Solving Problems	10%	805

G18. A stream of alpha particles is directed at a very thin sheet of gold.

Explain why most of the alpha particles pass through the sheet.

Code	Response
	Correct Response
20	Explains that the diameter of a gold atom (or the distance between the nuclei) is very large compared to the diameter of a nucleus and an alpha particle. (Collisions with electrons will not have significant effects.) *Example: Within an atom there is almost only empty space because the nucleus is small, and an atom is very large compared to an alpha particle.*
29	Other correct.
	Partial Response
10	References general idea of empty space within the gold atom, but omits or incompletely describes relative sizes. *Example: An atom has a nucleus surrounded mostly by space so the alpha particles can pass through.*
19	Other partially correct.
	Incorrect Response
70	Refers to the fact that alpha particles have high (kinetic) energy (or high speed).
71	Refers to the fact that there is empty space **between** the atoms. *Example: The alpha particles just go around the gold atoms.*
72	Combination of code 70 and 71.
73	Refers to the wave nature (wavelength) of alpha particles.
74	Refers to the crystal structure of gold.
79	Other incorrect.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

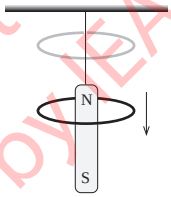
G19. A strong bar magnet hangs from a string with its north pole upwards. A light ring of aluminium is held above the magnet and allowed to fall down to the ground, as shown in the figure.



Explain why the ring takes longer to fall to the ground with the magnet present than it would without the magnet.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Electricity and Magnetism	Theorizing, Analyzing, and Solving Problems	14%	759

G19. A strong bar magnet hangs from a string with its north pole upwards. A light ring of aluminium is held above the magnet and allowed to fall down to the ground, as shown in the figure.



Explain why the ring takes longer to fall to the ground with the magnet present than it would without the magnet.

Note: A response may include the following aspects:

a) Changing flux while the ring is falling
b) Induction, i.e. induced current (or e.m.f.)
c) A force acting on the ring in the opposite direction of the motion
d) Reduced acceleration and therefore longer time to fall

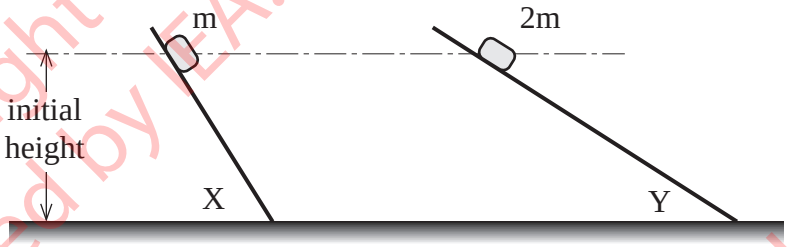
For a complete response b and c are regarded as crucial

Code	Response
	Correct Response
20	Response refers to b and c, and in addition a and/or d. *Examples: a) There's an induced current in the ring. According to Lenz's law, this creates a force acting opposite the movement (upwards) which decreases the acceleration of the ring.* *b) The flux will change which creates induced current and an upwards force acting on the ring.*
21	Refers to b and c only. *Example: Because of an induced e.m.f., there will be a magnetic force acting on the ring upwards.*
29	Other acceptable responses such as reasons including conservation of energy.
	Partial Response
10	Refers to induction (b) or Lenz' law, with incorrect (incomplete) or without further reasoning. *Example: In Lenz's law it states that the inducing current has a force acting on the induced current which will create an opposition force to the induced field.*
19	Other partially correct responses.

Continued Next Page

Incorrect Response	
70	Responses expressing the idea that the magnet pushes (or pulls) on the ring due to the magnetic force from the magnet. Nothing recorded about induction. *Examples: a) Because the magnetic field is a force acting on the ring, the ring will fall slower.* *b) As the ring leaves the presence of the magnet, the attractive force works against gravity.* *c) The magnet makes resistance.*
79	Other unacceptable responses.
Nonresponse	
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

H1. Two boxes of mass m and 2m are allowed to slide down inclined planes X and Y, starting from rest at the same height. The two planes are of different slope and offer negligible friction to the motion of the boxes.



Which one of the following statements is NOT correct?

A. At the top of the planes one of the boxes had half the potential energy of the other box.

B. The boxes have the same speed at the bottom of the inclined planes.

C. The boxes take the same time to reach the bottom of the inclined planes.

D. The box on plane X has greater acceleration than the box on plane Y.

H-1

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	C	Mechanics	Theorizing, Analyzing, and Solving Problems	39%	650

H2. Which one of the following statements about liquid evaporation is correct?

When a liquid evaporates

A. the temperature in the air above the liquid decreases.

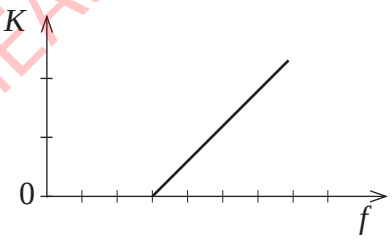
B. fast-moving liquid molecules near the surface escape to the air and the liquid gets warmer.

C. the gas pressure of the substance directly above the liquid depends only on the atmospheric pressure.

D. fast-moving liquid molecules near the surface escape to the air and the liquid gets colder.

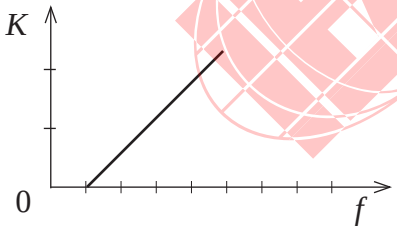
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	D	Heat	Understanding	54%	570

H3. The graph shows the maximum kinetic energy (K) of electrons emitted from a certain metal by the photoelectric effect as a function of the frequency (f) of the incoming radiation.



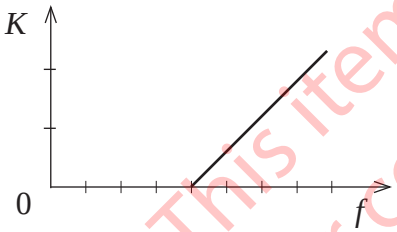
Which one of the following graphs best represents the kinetic energy-frequency relationship for another metal with a smaller work function? All the graphs have the same frequency scale and kinetic energy scale.

A.



B.

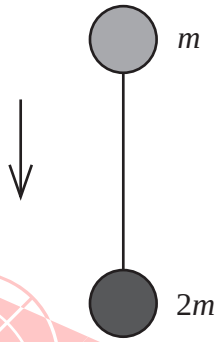
C.



D.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	A	Modern Physics: Particle, Quantum and Astrophysics, and Relativity	Using Tools, Routine Procedures, and Science Processes	39%	666

H4. Two spheres with masses m and $2m$ respectively are connected by a light string and suspended at rest. The system is released and falls freely, as shown in the figure.



If g is the acceleration due to gravity, what is the tension in the string as the system falls?

A. 0

B. mg

C. 2mg

D. 3mg

H-4

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	A	Mechanics	Theorizing, Analyzing, and Solving Problems	34%	696

H5. A spaceship passes an observer at a speed of 0.9 c. The observer knows that the length of the spaceship, measured at rest before it took off, was 100 m.

What is the length of the spaceship in flight as seen by the observer?

A. 19 m

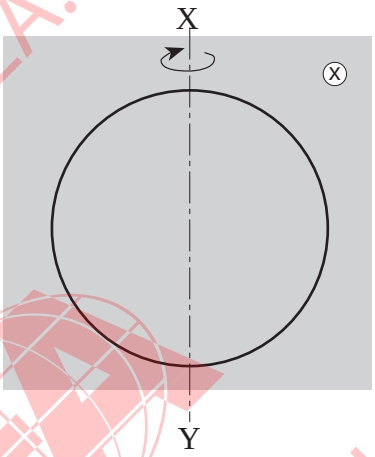
B. 44 m

C. 229 m

D. 526 m

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	B	Modern Physics: Particle, Quantum and Astrophysics, and Relativity	Theorizing, Analyzing, and Solving Problems	45%	619

H6. A circular wire coil rotates at a constant speed about the axis XY in a constant and uniform magnetic field ***B*** directed into the page. The figure shows the coil at an instant in which it lies in the plane of the page.



Magnetic field *B* into the page

After which of the following fractions of a rotation will the induced emf be a maximum?

A. 0

B. $\frac{1}{8}$

C. $\frac{1}{4}$

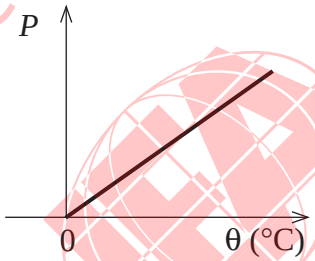
D. $\frac{1}{2}$

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	C	Electricity and Magnetism	Understanding	30%	716

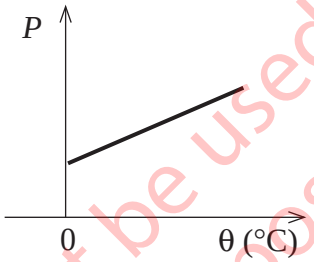
H7. A fixed mass of gas is heated at constant volume.

Which one of the following diagrams best shows the correct shape of the graph of pressure (*P*) against temperature (θ) for the gas? Temperature is measured in degrees Celsius (°C).

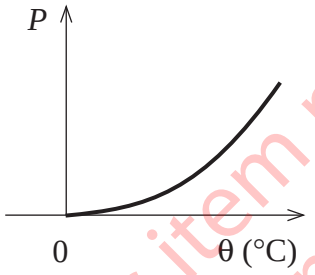
A.



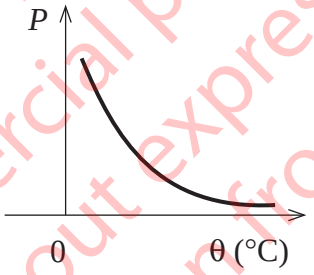
B.



C.

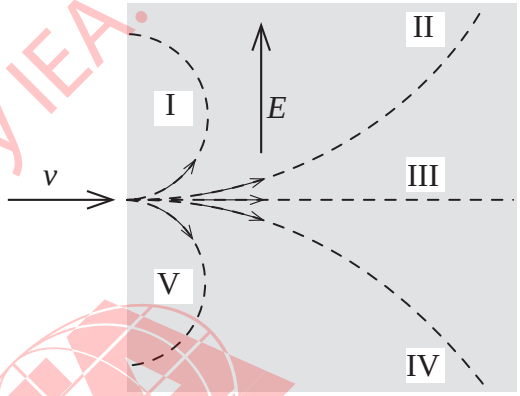


D.



Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	B	Heat	Using Tools, Routine Procedures, and Science Processes	41%	650

H8. Electrons enter a uniform electric field ***E*** with a velocity ***v*** as shown in the figure. The velocity ***v*** is perpendicular to the electric field ***E***.



Which one of the dashed paths (I, II, III, IV or V) best represents the path of the electrons in the electric field?

A. I

B. II

C. III

D. IV

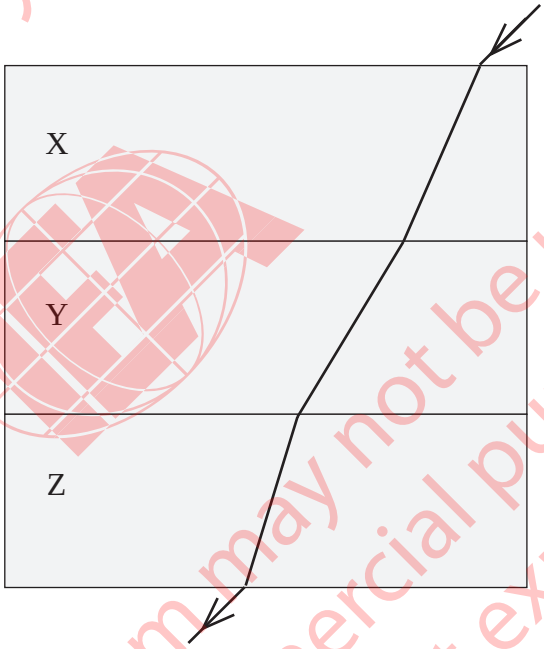
E. V

H-8

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	D	Electricity and Magnetism	Understanding	32%	711

H9. A ray of blue light passes through a stack of three parallel-sided blocks made of different materials. The path of the beam is shown.

In which of the three blocks is the velocity of blue light greatest?



A. X

B. Y

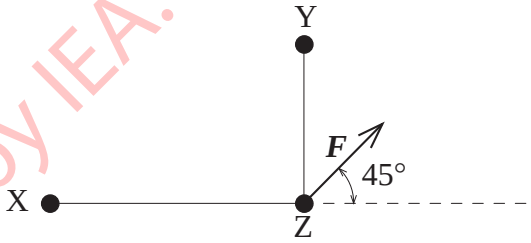
C. Z

D. The velocity is the same in all the blocks.

E. The information given is insufficient to be able to say.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	B	Wave Phenomena	Understanding	26%	747

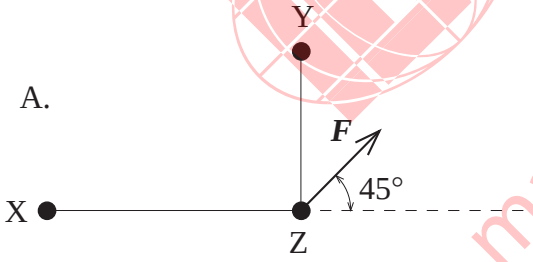
H10. The figure below shows three small charged spheres X, Y and Z. The distance between X and Z is greater than the distance between Y and Z. The vector sum of the electric forces on Z is denoted by ***F*.**



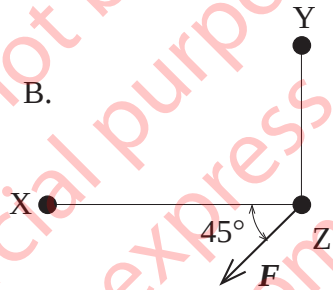
The two charged spheres X and Y are now interchanged.

Which one of the diagrams below best represents the vector sum of the electric forces on Z now?

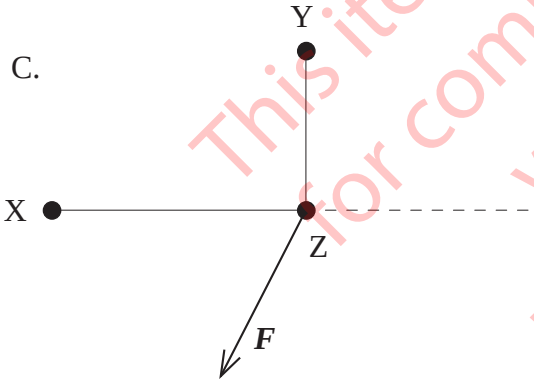
A.



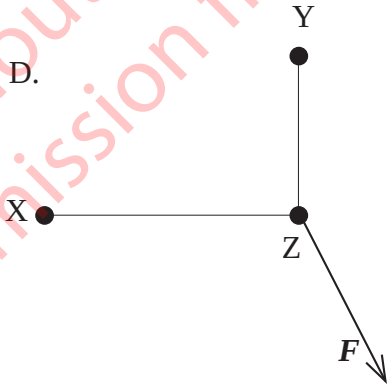
B.



C.

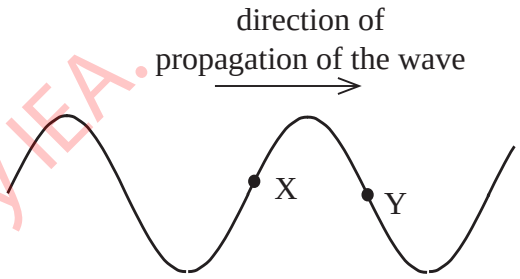


D.



Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	C	Electricity and Magnetism	Theorizing, Analyzing, and Solving Problems	32%	709

H12. The figure shows a wave moving to the right on a string.

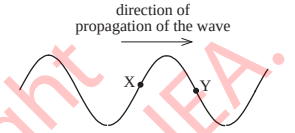


Draw an arrow at point X and one at point Y to show the direction of motion of the two points at the instant shown in the figure.

H-12

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Wave Phenomena	Theorizing, Analyzing, and Solving Problems	26%	752

H12. The figure shows a wave moving to the right on a string.

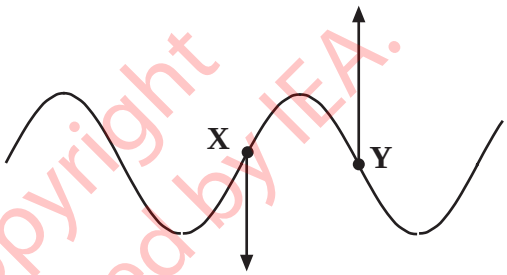


Draw an arrow at point X and one at point Y to show the direction of motion of the two points at the instant shown in the figure.

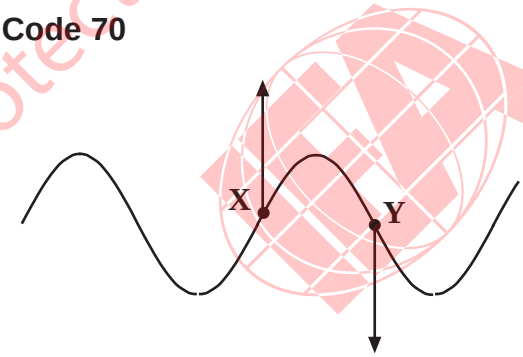
Code	Response
	Correct Response
10	Arrow downwards at X, upwards at Y. (See following diagram)
	Incorrect Response
70	Arrow upwards at X, downwards at Y.
71	Arrows to the right at both X and Y.
72	Arrows in direction of string motion at X and Y.
79	Other incorrect response.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

Continued Next Page

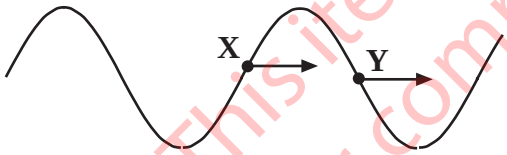
Code 10



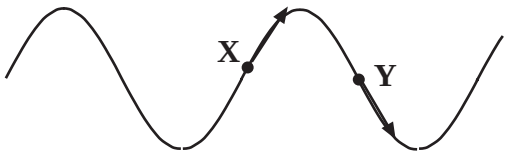
Code 70



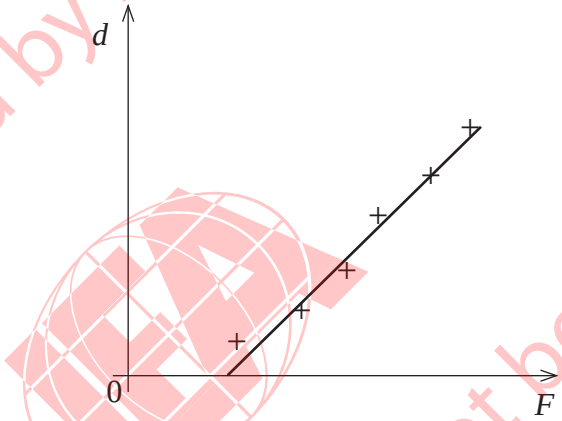
Code 71



Code 72



H13. A block is accelerated from rest along a horizontal table top by a constant unbalanced force ***F***. The experiment is repeated several times using a different value for the constant unbalanced force each time. For each force the distance *d* travelled by the block in the first 2.0 seconds is measured. The graph below shows the results of such an experiment.

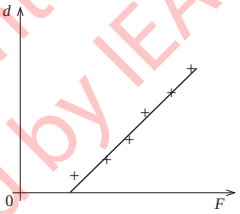


Explain why the graph line does not pass through the origin.

H-13

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Mechanics	Using Tools, Routine Procedures, and Science Processes	35%	690

H13. A block is accelerated from rest along a horizontal table top by a constant unbalanced force ***F***. The experiment is repeated several times using a different value for the constant unbalanced force each time. For each force the distance *d* travelled by the block in the first 2.0 seconds is measured. The graph below shows the results of such an experiment.

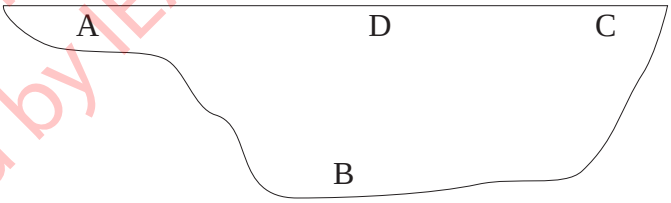


Explain why the graph line does not pass through the origin.

Note: Distinguish between students who mention friction, and those who do not.

Code	Response
	Correct Response
10	Refers to friction. Develops a formula for a graph outside origin. *Example: Newton's 2nd law gives: F – R = ma. And d = 1/2at^2. t is a constant, and this shows that d is proportional to F – R giving a straight line outside the origin.*
11	Refers to (static) friction. *Example: Because of friction there is a minimum value of the force before the block will move. Therefore the graph line will not pass through the origin.*
19	Other correct responses.
	Incorrect Response
70	Refers only to the fact that static friction is greater than kinetic friction.
71	Misinterpretation of the graph (e.g. one of the axes is time).
72	Refers to the fact that the force is not zero or cannot be zero.
79	Other incorrect responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

H14. Here is a cross-section of a lake in the mountains. The air temperature gets below freezing in the winter and stays below freezing for 3 months.

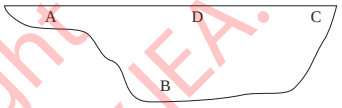


Not all of the water in the lake freezes. Which part of the lake will remain the warmest? Explain.

H-14

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Heat	Understanding	13%	804

H14. Here is a cross-section of a lake in the mountains. The air temperature gets below freezing in the winter and stays below freezing for 3 months.

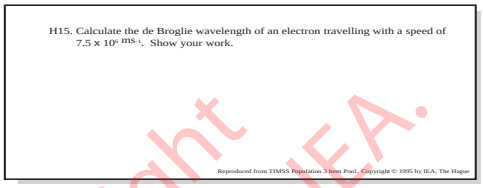


Not all of the water in the lake freezes. Which part of the lake will remain the warmest? Explain.

Code	Response
	Correct Response
20	B. Response refers to the maximum density of water (or the water is heaviest) at 4 degrees Celsius. *Example: Warmest at B because water has greatest density at 4˚ C so this water will stay there.*
29	Other acceptable responses.
	Partial Response
10	B. Refers to the fact that the water is 4 degrees Celsius at B without mentioning density.
11	B. Refers to the fact that ice will insulate this part of the water and/or that water is a bad heat conductor. *Examples: a) The surface will freeze first and then downwards.* *b) It takes time for heat and cold to get there.*
19	Other partially correct responses.
	Incorrect Response
70	B. No explanation.
71	B. Incorrect explanation referring to the heat from the earth (closer to the earth's center). *Example: The heat from the Earth will give heat to the water.*
72	B. Refers to the fact that hot water is heavier than cold water.
73	A/D/C with or without explanation.
76	Merely repeats information in the stem. *Example: B is the deepest point of the lake.*
79	Other unacceptable responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

H15. Calculate the de Broglie wavelength of an electron travelling with a speed of 7.5×10^6 ms^{-1}. Show your work.

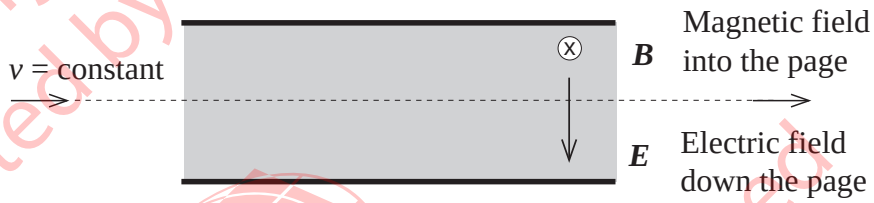
Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Modern Physics: Particle, Quantum and Astrophysics, and Relativity	Theorizing, Analyzing, and Solving Problems	25%	759


H15. Calculate the de Broglie wavelength of an electron travelling with a speed of 7.5×10^6 ms^{-1}. Show your work.

Note: Accept reasonable rounding and missing or wrong units.

Code	Response
	Correct Response
10	9.7 x 10^{-11} m: $\lambda = h/p = h/mv$.
11	9.7 x 10^{-11} m. No work shown.
12	9.7 x 10^{-11} m. Relativistic impulse (unnecessary) giving correct answer: $\lambda = \frac{h}{\frac{mv}{\sqrt{1-\frac{v^2}{c^2}}}}$
19	Other correct responses.
	Incorrect Response
70	Correct formula, but calculation missing or incorrect, such as exponential error.
71	$\lambda = v/f$, no conclusion.
79	Other incorrect responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

H16. An electron with charge e enters an area with a uniform magnetic field $\boldsymbol{B}$ and a uniform electric field $\boldsymbol{E}$. It continues its motion without any change in speed or direction of motion as the diagram shows. The magnetic field, directed into the page, is at right angles to the electric field, which is directed down the page.



Find an expression of the speed v of the electron in terms of E and B. Show your work.

H-16

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Electricity and Magnetism	Theorizing, Analyzing, and Solving Problems	21%	718

H16. An electron with charge *e* enters an area with a uniform magnetic field ***B*** and a uniform electric field ***E***. It continues its motion without any change in speed or direction of motion as the diagram shows. The magnetic field, directed into the page, is at right angles to the electric field, which is directed down the page.

Find an expression of the speed *v* of the electron in terms of *E* and *B*. Show your work.

Note: Vectors are shown in bold italic type

Code	Response
	Correct Response
20	***v*** = ***E***/***B*** (accept ***v*** = ***E***/***B***sin α) Balanced magnetic and electronic forces: q***vB*** = q***E***
21	***v*** = ***E***/***B*** (accept ***v*** = ***E***/***B***sin α.) Correct use of vector notation. *Example:* $q\mathbf{v} \times \mathbf{B} + q\mathbf{E} = 0$ *then* $q\mathbf{vB}(\sin \alpha) = q\mathbf{E}$ $\alpha = 90°$ *so* ***v*** = ***E***/***B***.
	Partial Response
10	Correct reasoning. Incorrect use of vector notation. *Example:* $q\mathbf{vB} = q\mathbf{E}$ *and then* ***v*** = ***E***/***B***
11	***v*** = ***E***/***B*** (accept ***v*** = ***E***/***B***sin α.) No work shown.
12	Correct formulas, but calculation error such as ***v*** = ***B***/***E***
13	Correct reasoning but one incorrect formula. (**Note**: Except II***B*** = q***vB*** is Code 79). *Example:* $F_1 = q\mathbf{vB}$ *and* $F_2 = qU$, *then* ***v*** = *U*/***B***
19	Other partially correct responses. *Example:* $F_B = q\mathbf{vB}$ *and* $F_E = q\mathbf{E}$
	Incorrect Response
70	Incorrect responses referring to circular motion.
79	Other incorrect responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

H17. A 15 watt light bulb requires a current of 1.7 ampere for normal operation. Suppose a 12 volt car battery is to be used. In order to have the bulb glow normally, a resistor is connected in series with the light bulb.

What resistance should this resistor have? (The internal resistance of the battery can be ignored.) Show your work.

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Electricity and Magnetism	Theorizing, Analyzing, and Solving Problems	17%	745

H17. A 15 watt light bulb requires a current of 1.7 ampere for normal operation. Suppose a 12 volt car battery is to be used. In order to have the bulb glow normally, a resistor is connected in series with the light bulb.

What resistance should this resistor have? (The internal resistance of the battery can be ignored.) Show your work.

Code	Response
	Correct Response
20	r = 1.9 Ω. Starts by calculating the total resistance (7.1 Ω) and/or the resistance of the bulb (5.2 Ω). *Examples: a)* $R_{bulb} = P/I^2 = 15W/(1.7A)^2 = 5.2\Omega$ $R = R_{tot} - R_{bulb} = \frac{12V}{1.7A} - 5.2 = 1.9\Omega$ *b)* $R_T = \frac{V}{I} = \frac{12V}{1.7A} = 7.1\Omega$ $7.1\Omega = R + (15W/(1.7A)^2)$ $R = 7.1\Omega - 5.2\Omega = 1.9\Omega$
21	r = 1.9 Ω. Starts with the calculation of the voltage across the bulb (8.8 V). *Example:* $V_{bulb} = P/I = 15W/1.7A = 8.8V$ $12V - 8.8V = 3.17V$ $R = \frac{V}{I} = \frac{3.17V}{1.7A} = 1.87\Omega$
29	r = 1.9 Ω. Other approaches.
	Partial Response
10	r = 1.9 Ω. No work shown.
11	As code 20. Correct reasoning, but calculation error.
12	As code 21. Correct reasoning, but calculation error.
19	Other partially correct responses. (**Note:** This code should only be used if the student has arrived at some numeric solution of the the problem given).
	Incorrect Response
70	r = 12 V / 1.7 A = 7.1 Ω. Calculates total resistance.
71	Calculates the resistance of the bulb (about 5.2 Ω).
72	r = I / U = 1.7 / 12 V = 0.14 Ω. Inverts R = V/I relationship.
79	Other incorrect responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret
99	BLANK

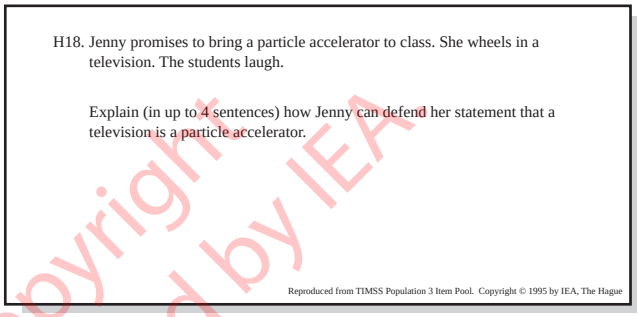
H18. Jenny promises to bring a particle accelerator to class. She wheels in a television. The students laugh.

Explain (in up to 4 sentences) how Jenny can defend her statement that a television is a particle accelerator.

H-18

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Modern Physics: Particle, Quantum and Astrophysics, and Relativity	Theorizing, Analyzing, and Solving Problems	15%	783

H-18 Coding Guide



H18. Jenny promises to bring a particle accelerator to class. She wheels in a television. The students laugh.

Explain (in up to 4 sentences) how Jenny can defend her statement that a television is a particle accelerator.

Code	Response
	Correct Response
20	Response refers to electron emission and acceleration by an electric field (in a cathode-ray tube/electron gun). *Examples: a) The electrons emit from the cathode and are accelerated by a high anode voltage.* *b) In a TV electrons are accelerated by an electric field.*
29	Other acceptable explanations.
	Partial Response
10	Refers to accelerated electrons. No further, or incorrect explanation. *Examples: Electrons are accelerated in a TV.* *In a TV there is an electron gun accelerating electrons.*
19	Other partially correct responses.
	Incorrect Response
70	Light (particles), photons or radioactive radiation (particles) are sent towards the screen.
76	Merely repeats information from the stem *Example: A TV accelerates particles.*
79	Other incorrect responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

H19.

(a) Briefly outline an experiment Susan could do at her school, using echos on the playground wall to measure the speed of sound. Indicate what materials Susan would need, what measurements she will take, and what computations she will make.

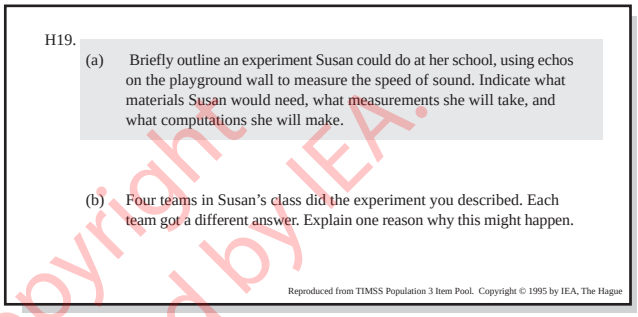
(b) Four teams in Susan's class did the experiment you described. Each team got a different answer. Explain one reason why this might happen.

H-19a

Part a

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Wave Phenomena	Investigating the Natural World	19%	747

H-19a Coding Guide



H19.

(a) Briefly outline an experiment Susan could do at her school, using echos on the playground wall to measure the speed of sound. Indicate what materials Susan would need, what measurements she will take, and what computations she will make.

(b) Four teams in Susan's class did the experiment you described. Each team got a different answer. Explain one reason why this might happen.

A: Outline of Experiment

Note: There are two variables for this item, one for each question, A and B.
Part A: Responses to this item should include the following three aspects:
i) Materials needed
ii) Description of the measurements of the distance and time.
iii) computation: Speed = distance/time (includes factor of 2x distance from source to wall)

Code	Response
	Correct Response
20	Response makes some reference to all three aspects, i, ii, iii.
29	Other acceptable responses such as using interference phenomena.
	Partial Response
10	Refers to two of the aspects, omits i.
11	Refers to two of the aspects, omits ii.
12	Refers to two of the aspects, omits iii.
13	Refers to all three aspects but with error in c, such as inconsistency, or a factor of 2 error in distance or time.
19	Other partially correct responses.
	Incorrect Response
70	Two of the aspects not adequately described.
79	Other unacceptable responses.
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

H19.

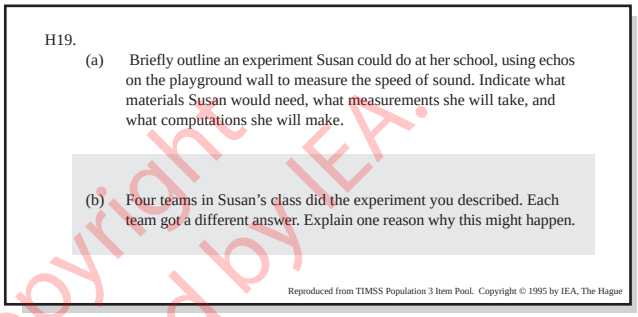
(a) Briefly outline an experiment Susan could do at her school, using echos on the playground wall to measure the speed of sound. Indicate what materials Susan would need, what measurements she will take, and what computations she will make.

(b) Four teams in Susan's class did the experiment you described. Each team got a different answer. Explain one reason why this might happen.

H-19b

Part b

Subject	Item Key	Content Category	Performance Expectation	International Average Percent of Students Responding Correctly	International Difficulty Index
Physics	next page	Wave Phenomena	Investigating the Natural World	45%	623



H19.

(a) Briefly outline an experiment Susan could do at her school, using echos on the playground wall to measure the speed of sound. Indicate what materials Susan would need, what measurements she will take, and what computations she will make.

(b) Four teams in Susan's class did the experiment you described. Each team got a different answer. Explain one reason why this might happen.

B: Why this might happen

Code	Response
	Correct Response
10	Acceptable reasons referring to measurement uncertainty/error, due to **equipment.** *Examples: a) Different answer due to uncertainty in the very short time interval.* *b) Different answer due to uncertainty in distance.* *c) A stopwatch is not the best equipment to measure short time intervals.*
11	Acceptable reasons referring to errors/uncertainty due to **students.** *Examples: a) Different answer due to calculation error.* *b) Different answer due to misreadings.* *c) Different answer due to different reaction time.*
19	Other acceptable reasons. *Examples: a) Different answer due to variation in wind.* *b) Different answer due to experimental error.*
	Incorrect Response
79	Any unacceptable reason. *Examples: a) Different answer due to different temperature.* *b) Different answer due to different frequencies.*
	Nonresponse
90	Crossed-out/erased, illegible, or impossible to interpret.
99	BLANK

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