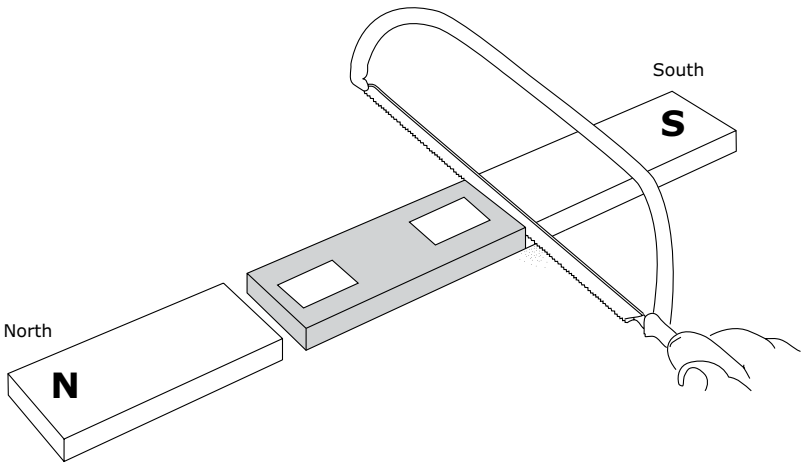
| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| **PHYSICS** | Electricity and Magnetism | Conceptual Understanding |

## Poles on cut magnet

The diagram shows a bar magnet which is cut into three pieces with a hacksaw.




Write an "N" or an "S" in each box on the diagram to show the polarity of each end of the center piece.

*Item Number: S022035*

## SCORING

Note: To receive credit, the polarity of BOTH ends of the center piece must be indicated. Answer is correct if polarity is indicated correctly (N-S), but letters are shown above, below, or outside the boxes, as long as the polarity of both ends of the center piece is clear.

### Correct Response

- N-S

### Incorrect Response

- S-N
- Pole of cut ends of outer pieces are indicated (S - N) instead of poles on center piece.
- Other incorrect (including crossed out/erased, stray marks, illegible, or off task).

## Overall Percent Correct

| | | |
|---|---|---|
| Japan | 64 | ▲ |
| Singapore | 62 | ▲ |
| Macedonia, Republic of | 62 | ▲ |
| Korea, Republic of | 59 | ▲ |
| Bahrain | 58 | ▲ |
| Sweden | 58 | ▲ |
| Lithuania | 56 | ▲ |
| Belgium (Flemish) | 55 | ▲ |
| Cyprus | 53 | ▲ |
| Russian Federation | 52 | ▲ |
| New Zealand | 51 | ▲ |
| Australia | 51 | ▲ |
| United States | 51 | ▲ |
| Estonia | 51 | ▲ |
| Serbia and Montenegro | 51 | ▲ |
| Israel | 51 | ▲ |
| Netherlands | 49 | O |
| Bulgaria | 48 | O |
| Italy | 48 | O |
| Morocco | 47 | O |
| Scotland | 47 | O |
| Moldova, Rep. of | 46 | O |
| Romania | 46 | O |
| England | 46 | O |
| Latvia | 45 | O |
| Slovenia | 45 | O |
| **International average** | **44** | |
| Chinese Taipei | 44 | O |
| Slovak Republic | 43 | O |
| Hungary | 43 | O |
| Malaysia | 43 | O |
| Norway | 41 | O |
| Hong Kong, SAR | 40 | ▼ |
| Botswana | 39 | ▼ |
| Jordan | 38 | ▼ |
| Saudi Arabia | 37 | ▼ |
| Lebanon | 36 | ▼ |
| Chile | 35 | ▼ |
| Philippines | 34 | ▼ |
| Tunisia | 33 | ▼ |
| Indonesia | 32 | ▼ |
| Iran, Islamic Republic of | 32 | ▼ |
| Egypt | 30 | ▼ |
| Palestinian Nat'l Auth. | 27 | ▼ |
| Armenia | 25 | ▼ |
| Ghana | 19 | ▼ |
| South Africa | 17 | ▼ |

**Country average vs. International average:**

| | |
|---|---|
| Higher | ▲ |
| Not different | O |
| Lower | ▼ |

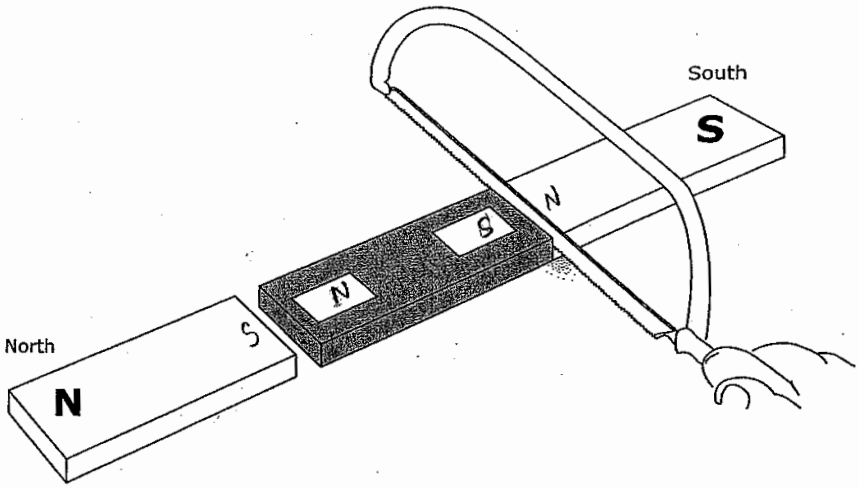
## Poles on cut magnet (continued)

*Item Number: S022035*

# Student Responses

### Correct Response:

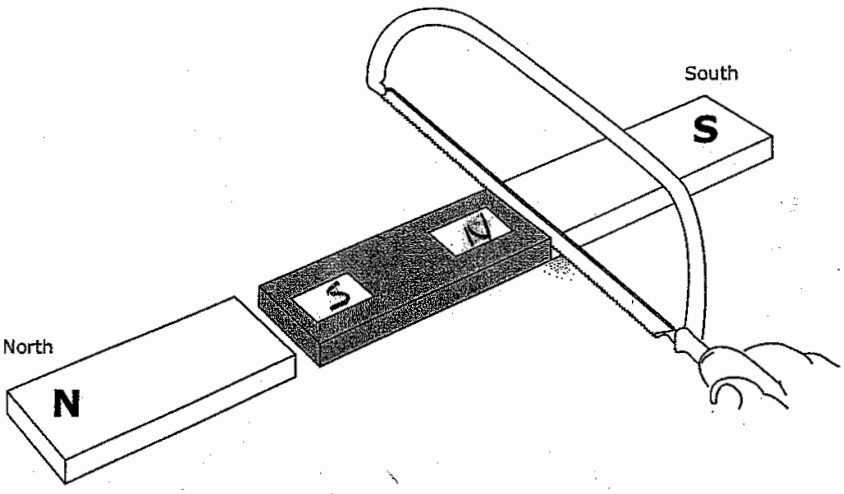
The diagram shows a bar magnet which is cut into three pieces with a hacksaw.




Write an "N" or an "S" in each box on the diagram to show the polarity of each end of the center piece.

### Incorrect Response:

The diagram shows a bar magnet which is cut into three pieces with a hacksaw.

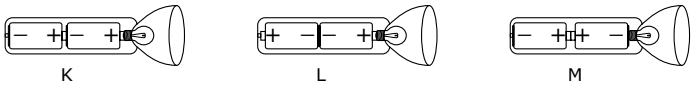



Write an "N" or an "S" in each box on the diagram to show the polarity of each end of the center piece.

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| **PHYSICS** | Electricity and Magnetism | Factual Knowledge |

## Diagram of batteries in a flashlight

The diagrams show a flashlight and three ways to put batteries in it.




In order to make the flashlight work, which way must the batteries be placed?

Ⓐ Only as in K

Ⓑ Only as in L

Ⓒ Only as in M

Ⓓ None of these ways would work.

*Item Number: S012037*

**Correct Response: A**

**Overall Percent Correct**

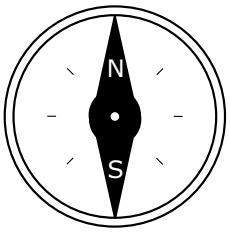
| | | |
|---|---|---|
| Singapore | 97 | ▲ |
| England | 95 | ▲ |
| Korea, Republic of | 93 | ▲ |
| Japan | 93 | ▲ |
| Hong Kong, SAR | 93 | ▲ |
| Russian Federation | 93 | ▲ |
| Slovak Republic | 93 | ▲ |
| Estonia | 93 | ▲ |
| Chinese Taipei | 92 | ▲ |
| Malaysia | 91 | ▲ |
| Romania | 91 | ▲ |
| Latvia | 91 | ▲ |
| Hungary | 91 | ▲ |
| Bulgaria | 91 | ▲ |
| Bahrain | 90 | ▲ |
| Lithuania | 90 | ▲ |
| Moldova, Rep. of | 90 | ▲ |
| Sweden | 89 | ▲ |
| United States | 89 | ▲ |
| Armenia | 88 | ▲ |
| New Zealand | 88 | O |
| Slovenia | 87 | ▲ |
| Lebanon | 86 | O |
| Netherlands | 86 | O |
| Australia | 85 | O |
| Belgium (Flemish) | 85 | O |
| Cyprus | 85 | O |
| **International average** | **85** | |
| Scotland | 84 | O |
| Indonesia | 84 | O |
| Serbia and Montenegro | 84 | O |
| Macedonia, Republic of | 84 | O |
| Italy | 83 | O |
| Iran, Islamic Republic of | 83 | O |
| Chile | 82 | O |
| Israel | 82 | O |
| Norway | 81 | ▼ |
| Botswana | 81 | ▼ |
| Morocco | 81 | O |
| Jordan | 78 | ▼ |
| Saudi Arabia | 78 | ▼ |
| Palestinian Nat'l Auth. | 78 | ▼ |
| Philippines | 77 | ▼ |
| Egypt | 67 | ▼ |
| Tunisia | 59 | ▼ |
| Ghana | 55 | ▼ |
| South Africa | 52 | ▼ |

**Country average vs. International average:**

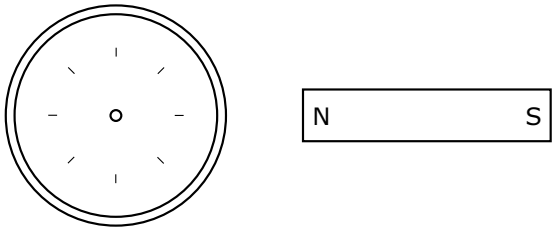
Higher ▲
Not different O
Lower ▼

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| **PHYSICS** | Electricity and Magnetism | Reasoning and Analysis |

## Compass placed next to a magnet/draw




The diagram above shows a compass needle with its North and South poles labeled (N and S). It is placed next to a strong magnet as shown in the diagram below.




A. Draw the compass needle in the circle on the diagram above. Label the North (N) and South (S) poles of the needle.

B. Explain your answer using your knowledge of magnets.

*Item Number: S032625A*

## SCORING

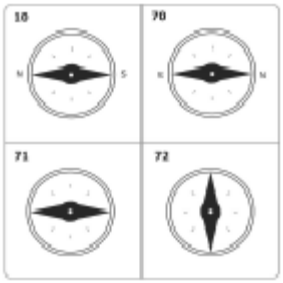
### Correct Response

- Draws a "horizontal" needle with N to the left and S to the right. [See diagram below.]

Note: Credit should be given even if one label is missing (N to the left OR S to the right shown).

### Incorrect Response

- Draws a "horizontal" needle with poles reversed (N to the right and/or S to the left). [See diagram below.]
- Draws a "horizontal" needle with no poles indicated. [See diagram below.]
- Draws a "vertical" needle with or without poles indicated. [See diagram below.]
- Other incorrect (including crossed out/erased, stray marks, illegible, or off task).




## Overall Percent Correct

| | | |
|---|---|---|
| Japan | 88 | ▲ |
| Korea, Republic of | 87 | ▲ |
| Chinese Taipei | 86 | ▲ |
| Singapore | 76 | ▲ |
| Slovak Republic | 74 | ▲ |
| Hungary | 67 | ▲ |
| England | 65 | ▲ |
| Hong Kong, SAR | 61 | ▲ |
| Malaysia | 58 | ▲ |
| Bulgaria | 57 | ▲ |
| Bahrain | 56 | ▲ |
| Armenia | 54 | ▲ |
| Sweden | 52 | ▲ |
| Australia | 50 | ▲ |
| Russian Federation | 48 | ▲ |
| Romania | 45 | ▲ |
| Serbia and Montenegro | 45 | ▲ |
| United States | 45 | ▲ |
| Netherlands | 44 | O |
| Iran, Islamic Republic of | 43 | O |
| Scotland | 41 | O |
| **International average** | **40** | |
| Jordan | 38 | O |
| Moldova, Rep. of | 37 | O |
| Italy | 33 | ▼ |
| Macedonia, Republic of | 33 | ▼ |
| Palestinian Nat'l Auth. | 33 | ▼ |
| Lebanon | 31 | ▼ |
| New Zealand | 31 | ▼ |
| Norway | 30 | ▼ |
| Estonia | 29 | ▼ |
| Morocco | 28 | ▼ |
| Israel | 27 | ▼ |
| Indonesia | 26 | ▼ |
| Egypt | 26 | ▼ |
| Slovenia | 25 | ▼ |
| Belgium (Flemish) | 25 | ▼ |
| Tunisia | 24 | ▼ |
| Latvia | 23 | ▼ |
| Lithuania | 21 | ▼ |
| Cyprus | 20 | ▼ |
| Philippines | 17 | ▼ |
| Saudi Arabia | 16 | ▼ |
| Chile | 15 | ▼ |
| Botswana | 14 | ▼ |
| South Africa | 5 | ▼ |
| Ghana | 2 | ▼ |

**Country average vs. International average:**

Higher ▲
Not different O
Lower ▼

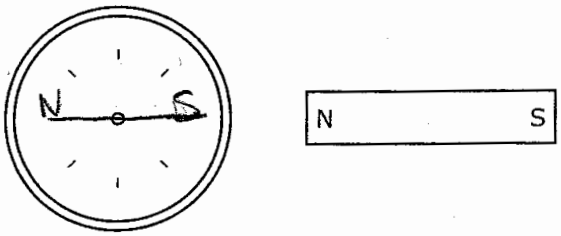
## Compass placed next to a magnet/draw (continued)

*Item Number: S032625A*

# Student Responses

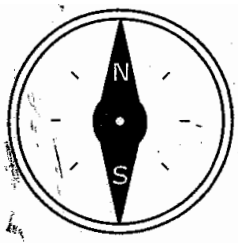
### Correct Response:

The diagram above shows a compass needle with its North and South poles labeled (N and S). It is placed next to a strong magnet as shown in the diagram below.

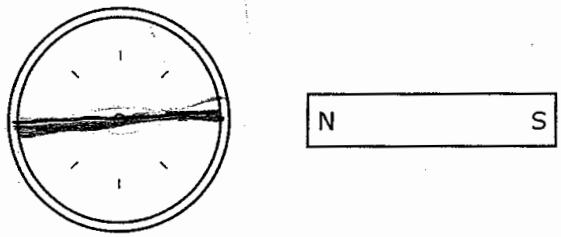



A. Draw the compass needle in the circle on the diagram above. Label the North (N) and South (S) poles of the needle.

### Incorrect Response:



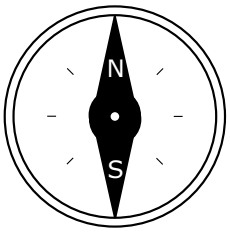

The diagram above shows a compass needle with its North and South poles labeled (N and S). It is placed next to a strong magnet as shown in the diagram below.



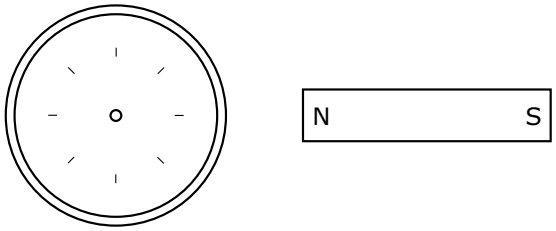

A. Draw the compass needle in the circle on the diagram above. Label the North (N) and South (S) poles of the needle.

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| **PHYSICS** | Electricity and Magnetism | Reasoning and Analysis |

## Compass placed next to a magnet/explain




The diagram above shows a compass needle with its North and South poles labeled (N and S). It is placed next to a strong magnet as shown in the diagram below.




A. Draw the compass needle in the circle on the diagram above. Label the North (N) and South (S) poles of the needle.

B. Explain your answer using your knowledge of magnets.

*Item Number: S032625B*

## Scoring for Explanation

### Correct Response

- Explains that opposite poles attract (N toward S, etc.) or like poles repel (or similar).
  *Examples: The south point of the compass is attracted to the north pole of the magnet.*
  *North and south attract together.*
  *The magnets which have different poles attract one another.*
  *The N pole on the magnet will attract the S pole on the compass.*
  *Opposites attract and likes repel.*
  *The magnet pushes the N pole of the compass away.*
- Other correct.

### Incorrect Response

- Refers to magnetic attraction/repulsion but with an incorrect application.
  *Examples: Because the same pole will be attracted.*
  *The magnet is closer to the compass and will have a stronger attraction to the N end.*
  *The needle of the compass is metal, so it is attracted to the magnet and turns.*
  *It attracts the needle to North and South poles.*
- Explains that the compass needle always points North, or similar.
  *Examples: The needle of North always goes to the magnetic North.*
  *North always goes toward North.*
- Other incorrect (including crossed out/erased, stray marks, illegible, or off task).

## Overall Percent Correct

| | | |
|---|---|---|
| Korea, Republic of | 81 | ▲ |
| Japan | 77 | ▲ |
| Chinese Taipei | 70 | ▲ |
| Singapore | 67 | ▲ |
| Hungary | 59 | ▲ |
| England | 59 | ▲ |
| Slovak Republic | 56 | ▲ |
| Hong Kong, SAR | 47 | ▲ |
| Armenia | 45 | ▲ |
| Bahrain | 43 | ▲ |
| Malaysia | 43 | ▲ |
| Bulgaria | 42 | ▲ |
| Australia | 41 | ▲ |
| Iran, Islamic Republic of | 40 | ▲ |
| Sweden | 39 | ▲ |
| United States | 37 | ▲ |
| Serbia and Montenegro | 37 | ▲ |
| Romania | 33 | O |
| Netherlands | 31 | O |
| Jordan | 30 | O |
| Palestinian Nat'l Auth. | 30 | O |
| **International average** | **29** | |
| Russian Federation | 29 | O |
| Moldova, Rep. of | 28 | O |
| Scotland | 28 | O |
| Macedonia, Republic of | 21 | ▼ |
| Italy | 20 | ▼ |
| Indonesia | 20 | ▼ |
| Egypt | 17 | ▼ |
| New Zealand | 17 | ▼ |
| Israel | 16 | ▼ |
| Lebanon | 16 | ▼ |
| Morocco | 14 | ▼ |
| Estonia | 13 | ▼ |
| Norway | 13 | ▼ |
| Botswana | 11 | ▼ |
| Belgium (Flemish) | 11 | ▼ |
| Slovenia | 10 | ▼ |
| Saudi Arabia | 9 | ▼ |
| Tunisia | 9 | ▼ |
| Philippines | 8 | ▼ |
| Latvia | 8 | ▼ |
| Chile | 5 | ▼ |
| Lithuania | 5 | ▼ |
| South Africa | 4 | ▼ |
| Cyprus | 4 | ▼ |
| Ghana | 2 | ▼ |

**Country average vs. International average:**

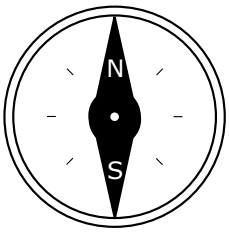
Higher ▲
Not different O
Lower ▼

## Compass placed next to a magnet/explain (continued)

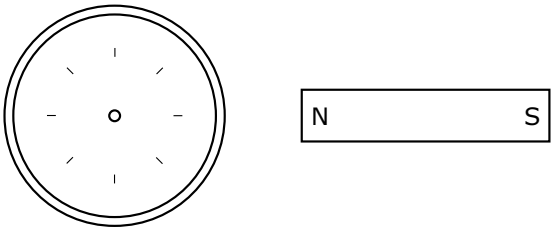
*Item Number: S032625B*

# Student Responses

### Correct Response:




The diagram above shows a compass needle with its North and South poles labeled (N and S). It is placed next to a strong magnet as shown in the diagram below.




B. Explain your answer using your knowledge of magnets.

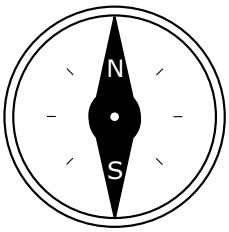
opposites attract and the north side of the magnet is facing the compass so the needle with south on it will point to the magnet

## Compass placed next to a magnet/explain (continued)

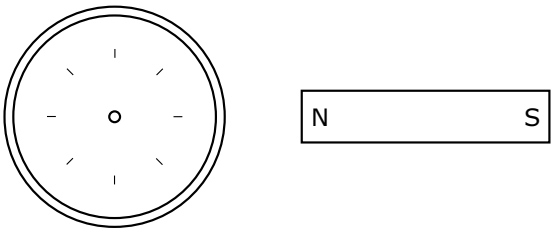
*Item Number: S032625B*

# Student Responses (continued)

### Incorrect Response:




The diagram above shows a compass needle with its North and South poles labeled (N and S). It is placed next to a strong magnet as shown in the diagram below.



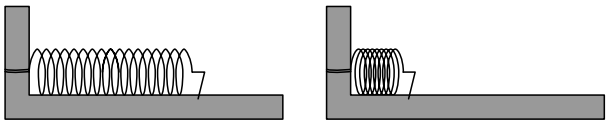

B. Explain your answer using your knowledge of magnets.

As the magnet contects the magnet moves the opposite way.

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| PHYSICS | Energy Types, Sources and Conversions | Conceptual Understanding |

## Stored energy in two springs

Spring 1 and Spring 2 were the same. Then, Spring 1 was pushed together a little and clamped in place. Spring 2 was pushed together a lot and clamped.



1 2

Which spring has more stored energy?

Ⓐ Spring 1

Ⓑ Spring 2

Ⓒ Spring 2

Ⓓ You cannot tell unless you know what the springs are made of.

*Item Number: S012002*

**Correct Response: B**

### Overall Percent Correct

| | | |
|---|---|---|
| Singapore | 84 | ▲ |
| England | 84 | ▲ |
| Korea, Republic of | 84 | ▲ |
| United States | 83 | ▲ |
| New Zealand | 83 | ▲ |
| Japan | 81 | ▲ |
| Netherlands | 79 | ▲ |
| Australia | 78 | ▲ |
| Scotland | 78 | ▲ |
| Estonia | 77 | ▲ |
| Hungary | 75 | ▲ |
| Italy | 75 | ▲ |
| Norway | 74 | ▲ |
| Lithuania | 74 | ▲ |
| Russian Federation | 73 | ▲ |
| Belgium (Flemish) | 71 | ▲ |
| Sweden | 71 | ▲ |
| Israel | 70 | ▲ |
| Hong Kong, SAR | 69 | ▲ |
| Slovenia | 68 | ▲ |
| Malaysia | 67 | ▲ |
| Latvia | 64 | O |
| Chinese Taipei | 64 | O |
| Lebanon | 63 | O |
| Jordan | 63 | O |
| **International average** | **62** | |
| Bulgaria | 61 | O |
| Armenia | 60 | O |
| Chile | 59 | O |
| Cyprus | 58 | O |
| Indonesia | 57 | ▼ |
| Iran, Islamic Republic of | 56 | ▼ |
| Macedonia, Republic of | 56 | ▼ |
| Serbia and Montenegro | 55 | ▼ |
| Botswana | 52 | ▼ |
| Palestinian Nat'l Auth. | 50 | ▼ |
| Philippines | 48 | ▼ |
| Slovak Republic | 47 | ▼ |
| Morocco | 46 | ▼ |
| Romania | 39 | ▼ |
| South Africa | 39 | ▼ |
| Egypt | 39 | ▼ |
| Moldova, Rep. of | 38 | ▼ |
| Saudi Arabia | 37 | ▼ |
| Ghana | 36 | ▼ |
| Bahrain | 35 | ▼ |
| Tunisia | 28 | ▼ |

**Country average vs. International average:**

Higher ▲
Not different O
Lower ▼

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| PHYSICS | Energy Types, Sources and Conversions | Conceptual Understanding |

## Nail pulled out of a wooden board

When a nail is pulled out of a wooden board, the nail becomes warm. Explain why.

*Item Number: S032131*

## SCORING

### Correct Response

- Explanation refers to friction (implicitly or explicitly).
  *Examples: Because it is rubbed against the wood.*
  *Nail resists when you pull it out.*
  *Because of the force on the nail to pull it out.*
  *Because of friction.*
  *There is friction between the nail and the wooden board.*
- Explanation refers to energy change.
  *Examples: There is more energy in the nail after the transition.*
  *Because energy is used to get it out.*
  *Kinetic energy changes to heat energy when you pull it out.*
- Other correct.

### Incorrect Response

- Explanation refers only to the nail or the action taken with inadequate connection to friction or energy.
  *Examples: It is hard to get it out.*
  *You must pull hard.*
  *Because it was in the wood for too long.*
- Other incorrect (including crossed out/erased, stray marks, illegible, or off task).

## Overall Percent Correct

| | | |
|---|---|---|
| Chinese Taipei | 84 | ▲ |
| Hungary | 84 | ▲ |
| Slovak Republic | 78 | ▲ |
| England | 75 | ▲ |
| Hong Kong, SAR | 74 | ▲ |
| Japan | 74 | ▲ |
| United States | 73 | ▲ |
| Russian Federation | 72 | ▲ |
| Lithuania | 72 | ▲ |
| Netherlands | 71 | ▲ |
| Australia | 71 | ▲ |
| Korea, Republic of | 70 | ▲ |
| Latvia | 68 | ▲ |
| Singapore | 67 | ▲ |
| Estonia | 66 | ▲ |
| Scotland | 66 | ▲ |
| Armenia | 66 | ▲ |
| Belgium (Flemish) | 64 | ▲ |
| Romania | 64 | ▲ |
| Malaysia | 63 | ▲ |
| Moldova, Rep. of | 62 | ▲ |
| Bulgaria | 61 | ▲ |
| New Zealand | 57 | O |
| Slovenia | 54 | O |
| **International average** | **52** | |
| Iran, Islamic Republic of | 52 | O |
| Sweden | 51 | O |
| Israel | 48 | O |
| Norway | 47 | ▼ |
| Jordan | 44 | ▼ |
| Cyprus | 44 | ▼ |
| Serbia and Montenegro | 44 | ▼ |
| Macedonia, Republic of | 41 | ▼ |
| Palestinian Nat'l Auth. | 40 | ▼ |
| Italy | 40 | ▼ |
| Chile | 40 | ▼ |
| Indonesia | 39 | ▼ |
| Bahrain | 33 | ▼ |
| Morocco | 27 | ▼ |
| Tunisia | 27 | ▼ |
| Saudi Arabia | 26 | ▼ |
| Philippines | 24 | ▼ |
| Lebanon | 22 | ▼ |
| Egypt | 20 | ▼ |
| Botswana | 11 | ▼ |
| South Africa | 11 | ▼ |
| Ghana | 5 | ▼ |

**Country average vs. International average:**

| | |
|---|---|
| Higher | ▲ |
| Not different | O |
| Lower | ▼ |

## Nail pulled out of a wooden board (continued)

*Item Number: S032131*

# Student Responses

### Correct Response:

When a nail is pulled out of a wooden board, the nail becomes warm. Explain why.

The nail becomes warm because of the energy that was in it as it was pulled out.

### Incorrect Response:

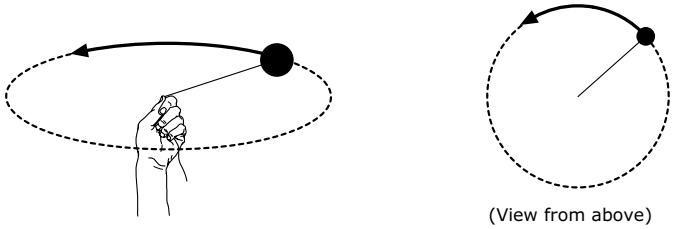
When a nail is pulled out of a wooden board, the nail becomes warm. Explain why.

Because the inside of the board is warmer than it is on the outside

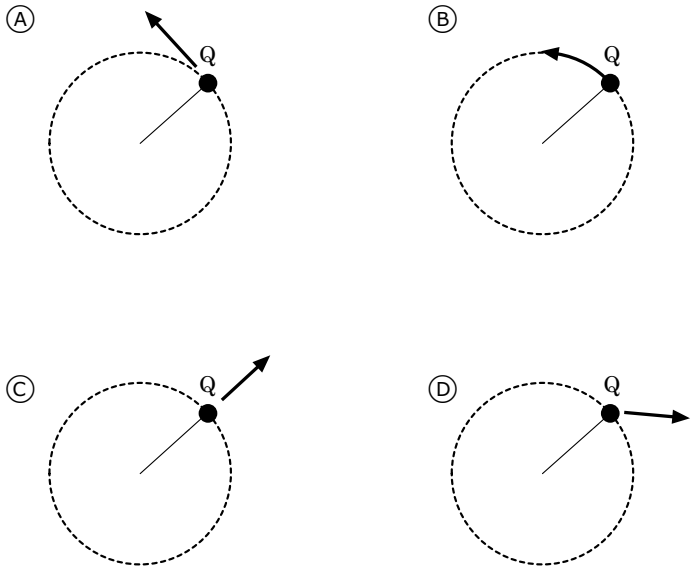
| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| **PHYSICS** | Forces and Motion | Conceptual Understanding |

## Path of ball released from orbit

The diagram on the left shows a ball on the end of a string being whirled in a circle. The diagram on the right shows the whirling ball as viewed from above.




After several whirls, the string is released when the ball is at Q. Which of these diagrams shows the direction in which the ball will fly the instant the string is released?




*Item Number: S022040*

**Correct Response: A**

### Overall Percent Correct

| | | |
|---|---|---|
| Korea, Republic of | 87 | ▲ |
| Netherlands | 82 | ▲ |
| Estonia | 80 | ▲ |
| Singapore | 79 | ▲ |
| Australia | 77 | ▲ |
| Japan | 77 | ▲ |
| Hungary | 77 | ▲ |
| Scotland | 77 | ▲ |
| New Zealand | 77 | ▲ |
| Belgium (Flemish) | 76 | ▲ |
| United States | 76 | ▲ |
| Lithuania | 75 | ▲ |
| Malaysia | 75 | ▲ |
| Sweden | 74 | ▲ |
| England | 74 | ▲ |
| Russian Federation | 74 | ▲ |
| Slovak Republic | 72 | ▲ |
| Norway | 72 | ▲ |
| Latvia | 71 | ▲ |
| Slovenia | 70 | ▲ |
| Hong Kong, SAR | 69 | ▲ |
| Chinese Taipei | 68 | ▲ |
| Italy | 61 | O |
| Bulgaria | 60 | O |
| Serbia and Montenegro | 60 | O |
| **International average** | **60** | |
| Cyprus | 59 | O |
| Israel | 58 | O |
| Romania | 58 | O |
| Chile | 58 | O |
| Armenia | 58 | O |
| Macedonia, Republic of | 54 | ▼ |
| Moldova, Rep. of | 52 | ▼ |
| Iran, Islamic Republic of | 48 | ▼ |
| Jordan | 47 | ▼ |
| Indonesia | 47 | ▼ |
| Bahrain | 44 | ▼ |
| Philippines | 42 | ▼ |
| Saudi Arabia | 38 | ▼ |
| Palestinian Nat'l Auth. | 36 | ▼ |
| Morocco | 33 | ▼ |
| Tunisia | 31 | ▼ |
| Egypt | 30 | ▼ |
| Lebanon | 30 | ▼ |
| Botswana | 30 | ▼ |
| South Africa | 22 | ▼ |
| Ghana | 22 | ▼ |

**Country average vs. International average:**

Higher ▲
Not different O
Lower ▼

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| **PHYSICS** | Forces and Motion | Conceptual Understanding |

## Why helium balloon moves upward

A balloon filled with helium gas is set free and starts to move upward.
Which of the following best explains why the helium balloon moves upward?

Ⓐ The density of helium is less than the density of air.

Ⓑ The air resistance lifts the balloon up.

Ⓒ There is no gravity acting on helium balloons.

Ⓓ The wind blows the balloon upward.

*Item Number: S032281*

**Correct Response: A**

**Overall Percent Correct**

| | | |
|---|---|---|
| Korea, Republic of | 89 | ▲ |
| Hungary | 88 | ▲ |
| Slovak Republic | 86 | ▲ |
| Chinese Taipei | 86 | ▲ |
| Estonia | 83 | ▲ |
| Singapore | 81 | ▲ |
| Slovenia | 79 | ▲ |
| Sweden | 77 | ▲ |
| Russian Federation | 75 | ▲ |
| Japan | 74 | ▲ |
| United States | 72 | ▲ |
| Hong Kong, SAR | 71 | ▲ |
| Malaysia | 69 | ▲ |
| Lithuania | 69 | ▲ |
| Norway | 69 | ▲ |
| Scotland | 69 | ▲ |
| Latvia | 69 | ▲ |
| New Zealand | 67 | ▲ |
| England | 66 | ▲ |
| Australia | 66 | ▲ |
| Serbia and Montenegro | 65 | ▲ |
| Romania | 65 | ▲ |
| Italy | 61 | O |
| Bulgaria | 60 | O |
| **International average** | **58** | |
| Netherlands | 58 | O |
| Jordan | 56 | O |
| Moldova, Rep. of | 56 | O |
| Armenia | 56 | O |
| Israel | 54 | ▼ |
| Chile | 52 | ▼ |
| Macedonia, Republic of | 52 | ▼ |
| Palestinian Nat'l Auth. | 50 | ▼ |
| Philippines | 49 | ▼ |
| Belgium (Flemish) | 49 | ▼ |
| Lebanon | 47 | ▼ |
| Egypt | 45 | ▼ |
| Bahrain | 43 | ▼ |
| Iran, Islamic Republic of | 38 | ▼ |
| Cyprus | 35 | ▼ |
| Saudi Arabia | 33 | ▼ |
| Indonesia | 32 | ▼ |
| Ghana | 28 | ▼ |
| Botswana | 25 | ▼ |
| South Africa | 21 | ▼ |
| Tunisia | 21 | ▼ |
| Morocco | 19 | ▼ |

**Country average vs. International average:**

Higher ▲
Not different O
Lower ▼

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| **PHYSICS** | Forces and Motion | Conceptual Understanding |

## Metal crown: why scientists repeated measurement

The scientists measured the volume of the crown five times. They computed the density for each volume measurement. Their results are shown in the table below.

| Trial | Volume of Crown ($cm^3$) | Density of Crown ($g/cm^3$) |
|---|---|---|
| 1 | 202 | 11.88 |
| 2 | 200 | 12.00 |
| 3 | 201 | 11.94 |
| 4 | 198 | 12.12 |
| 5 | 199 | 12.06 |

A. Why did the scientists measure the volume five times?

B. The scientists reported to the king that the density of the crown was 12.0 $g/cm^3$. Show how the scientists used their results to obtain this value for the density.

*Item Number: S032712A*

### Overall Percent Correct

| | | |
|---|---|---|
| Chinese Taipei | 76 | ▲ |
| Korea, Republic of | 67 | ▲ |
| Estonia | 60 | ▲ |
| Singapore | 58 | ▲ |
| Hong Kong, SAR | 56 | ▲ |
| Japan | 53 | ▲ |
| Malaysia | 53 | ▲ |
| Lithuania | 53 | ▲ |
| Belgium (Flemish) | 47 | ▲ |
| United States | 47 | ▲ |
| Australia | 44 | ▲ |
| Jordan | 44 | ▲ |
| Slovenia | 42 | ▲ |
| Sweden | 42 | ▲ |
| Scotland | 41 | ▲ |
| New Zealand | 40 | ▲ |
| Palestinian Nat'l Auth. | 38 | ▲ |
| Slovak Republic | 34 | O |
| England | 34 | O |
| Netherlands | 33 | O |
| Israel | 33 | O |
| **International average** | **30** | |
| Moldova, Rep. of | 30 | O |
| Latvia | 29 | O |
| Egypt | 29 | O |
| Russian Federation | 26 | ▼ |
| Serbia and Montenegro | 23 | ▼ |
| Norway | 22 | ▼ |
| Hungary | 22 | ▼ |
| Cyprus | 21 | ▼ |
| Morocco | 21 | ▼ |
| Tunisia | 19 | ▼ |
| Iran, Islamic Republic of | 18 | ▼ |
| Bahrain | 17 | ▼ |
| Macedonia, Republic of | 15 | ▼ |
| Indonesia | 15 | ▼ |
| Italy | 15 | ▼ |
| Romania | 14 | ▼ |
| Bulgaria | 13 | ▼ |
| Armenia | 11 | ▼ |
| Botswana | 10 | ▼ |
| Philippines | 8 | ▼ |
| Chile | 6 | ▼ |
| Lebanon | 6 | ▼ |
| South Africa | 6 | ▼ |
| Ghana | 5 | ▼ |
| Saudi Arabia | 1 | ▼ |

**Country average vs. International average:**

Higher ▲
Not different O
Lower ▼

# Metal crown: why scientists repeated measurement (continued)

*Item Number: S032712A*

## SCORING

### Why Scientists Repeat Measurements

**Correct Response**

- Refers to accuracy, precision, reliability, experimental uncertainty, estimation of measurement error (or similar).

  *Examples: Because there is experimental error. So measuring it 5 times you can calculate the average to know how much error there is.*

  *Each time they measure the volume it is close but not exactly the same. So, it's better to measure it a few times to be sure.*

  *They want a more exact answer.*

  *To get an accurate measure of the volume.*

  *It's more reliable.*

- Refers only to computing an average or mean value (or median or range).

  *Examples: To find the average volume.*

  *To work out the mean.*

- Other correct.

**Incorrect Response**

- Refers only to 'mistakes' or changes in the measurements (or similar); no explicit mention of accuracy, precision, experimental uncertainty, etc.

  *Examples: In case mistakes happen.*

  *To make sure it wasn't changing.*

  *To make sure the answer was right and he did not make a mistake.*

  *To make sure they did it right.*

  *To check if it was correct.*

- Refers only to a 'fair test' or similar; no explicit mention of computation of average, accuracy, precision, experimental uncertainty, etc.

  *Examples: To make sure it was a fair test.*

  *To ensure a fair test.*

- Other incorrect (including crossed out/erased, stray marks, illegible or off task).

## Metal crown: why scientists repeated measurement (continued)

*Item Number: S032712A*

# Student Responses

### Correct Response:

The scientists measured the volume of the crown five times. They computed the density for each volume measurement. Their results are shown in the table below.

| Trial | Volume of Crown ($cm^3$) | Density of Crown ($g/cm^3$) |
|---|---|---|
| 1 | 202 | 11.88 |
| 2 | 200 | 12.00 |
| 3 | 201 | 11.94 |
| 4 | 198 | 12.12 |
| 5 | 199 | 12.06 |

A. Why did the scientists measure the volume five times?

To test more than once to see if their answers are close to the other answers.

### Incorrect Response:

The scientists measured the volume of the crown five times. They computed the density for each volume measurement. Their results are shown in the table below.

| Trial | Volume of Crown ($cm^3$) | Density of Crown ($g/cm^3$) |
|---|---|---|
| 1 | 202 | 11.88 |
| 2 | 200 | 12.00 |
| 3 | 201 | 11.94 |
| 4 | 198 | 12.12 |
| 5 | 199 | 12.06 |

A. Why did the scientists measure the volume five times?

To see if they got a different answer, or they might of used s different object to measure,

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| PHYSICS | Forces and Motion | Conceptual Understanding |

## Metal crown: determination of average/median value

The scientists measured the volume of the crown five times. They computed the density for each volume measurement. Their results are shown in the table below.

| Trial | Volume of Crown ($cm^3$) | Density of Crown ($g/cm^3$) |
|---|---|---|
| 1 | 202 | 11.88 |
| 2 | 200 | 12.00 |
| 3 | 201 | 11.94 |
| 4 | 198 | 12.12 |
| 5 | 199 | 12.06 |

A. Why did the scientists measure the volume five times?

B. The scientists reported to the king that the density of the crown was 12.0 $g/cm^3$. Show how the scientists used their results to obtain this value for the density.

*Item Number: S032712B*

## SCORING

### Correct Response

- Shows (or describes) a correct method for computing the average (mean) value.
  *Examples: (11.88+12.00+11.94+12.12+12.06) = 60. 60/5=12.0*
  *(202+200+201+198+199)/5 = 200. 2400/200=12.0*
  *They added together all of the densities and then divided by 5 to get the average.*
- Shows (or describes) a correct method for determining the median value.
  *Examples: 202, 201, 200, 198, 199. 200 is the median volume, so 2400/200 is the median density (12).*
  *12 is the middle value when placed in order (12.12, 12.06, 12.00, 11.94, 11.88).*
- Other correct

### Incorrect Response

- States that it is the average, mean or median value with no or incorrect work shown.
- Shows a computation of density (mass/volume). [No determination of average or median included.]
  *Examples: They did mass divided by volume.*
  *2400g/200cc = 12 g/cc*
- Other incorrect (including crossed out/erased, stray marks, illegible, or off task).

## Overall Percent Correct

| | | |
|---|---|---|
| Singapore | 47 | ▲ |
| Japan | 44 | ▲ |
| Estonia | 36 | ▲ |
| Lithuania | 31 | ▲ |
| United States | 29 | ▲ |
| Netherlands | 29 | ▲ |
| Chinese Taipei | 28 | ▲ |
| Scotland | 26 | ▲ |
| Sweden | 24 | ▲ |
| Hong Kong, SAR | 24 | ▲ |
| Australia | 23 | ▲ |
| England | 22 | ▲ |
| Latvia | 22 | ▲ |
| New Zealand | 21 | ▲ |
| Malaysia | 20 | ▲ |
| Belgium (Flemish) | 20 | ▲ |
| Korea, Republic of | 15 | O |
| Norway | 14 | O |
| Slovenia | 14 | O |
| **International average** | **14** | |
| Israel | 13 | O |
| Moldova, Rep. of | 13 | O |
| Hungary | 12 | ▼ |
| Serbia and Montenegro | 11 | ▼ |
| Slovak Republic | 10 | ▼ |
| Russian Federation | 10 | O |
| Cyprus | 9 | ▼ |
| Bulgaria | 9 | ▼ |
| Romania | 7 | ▼ |
| Jordan | 7 | ▼ |
| Macedonia, Republic of | 7 | ▼ |
| Armenia | 6 | ▼ |
| Italy | 6 | ▼ |
| Lebanon | 6 | ▼ |
| Indonesia | 4 | ▼ |
| Tunisia | 4 | ▼ |
| Philippines | 4 | ▼ |
| Egypt | 4 | ▼ |
| Bahrain | 3 | ▼ |
| Palestinian Nat'l Auth. | 3 | ▼ |
| Chile | 3 | ▼ |
| Morocco | 3 | ▼ |
| Botswana | 2 | ▼ |
| Iran, Islamic Republic of | 2 | ▼ |
| South Africa | 1 | ▼ |
| Ghana | 1 | ▼ |
| Saudi Arabia | 0 | ▼ |

**Country average vs. International average:**

Higher ▲
Not different O
Lower ▼

## Metal crown: determination of average/median value (continued)

*Item Number: S032712B*

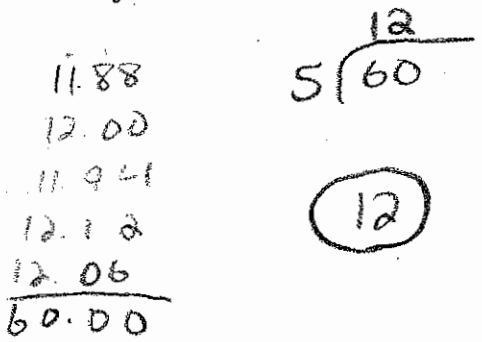
# Student Responses

### Correct Response:

The scientists measured the volume of the crown five times. They computed the density for each volume measurement. Their results are shown in the table below.

| Trial | Volume of Crown ($cm^3$) | Density of Crown ($g/cm^3$) |
|---|---|---|
| 1 | 202 | 11.88 |
| 2 | 200 | 12.00 |
| 3 | 201 | 11.94 |
| 4 | 198 | 12.12 |
| 5 | 199 | 12.06 |

B. The scientists reported to the king that the density of the crown was 12.0 $g/cm^3$. Show how the scientists used their results to obtain this value for the density.



## Metal crown: determination of average/median value (continued)

*Item Number: S032712B*

# Student Responses

### Incorrect Response:

The scientists measured the volume of the crown five times. They computed the density for each volume measurement. Their results are shown in the table below.

| Trial | Volume of Crown ($cm^3$) | Density of Crown ($g/cm^3$) |
|---|---|---|
| 1 | 202 | 11.88 |
| 2 | 200 | 12.00 |
| 3 | 201 | 11.94 |
| 4 | 198 | 12.12 |
| 5 | 199 | 12.06 |

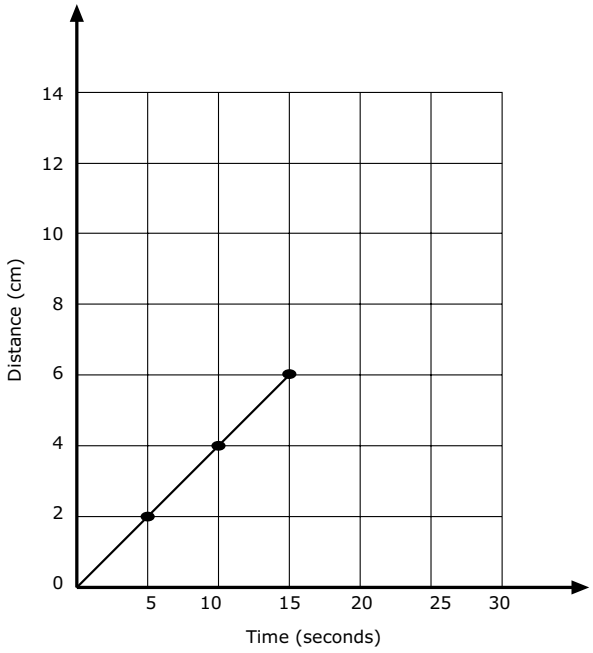
B. The scientists reported to the king that the density of the crown was 12.0 $g/cm^3$. Show how the scientists used their results to obtain this value for the density.

He took the average and used that.

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| **PHYSICS** | Forces and Motion | Reasoning and Analysis |

## Extrapolation of distance/time graph

The graph shows the progress made by a beetle moving along a straight line.




If the beetle keeps moving at the same speed, how long will it take to travel 10 cm?

Ⓐ 4 seconds

Ⓑ 6 seconds

Ⓒ 20 seconds

Ⓓ 25 seconds

*Item Number: S022041*

**Correct Response: D**

### Overall Percent Correct

| | | |
|---|---|---|
| Netherlands | 91 | ▲ |
| Singapore | 90 | ▲ |
| Korea, Republic of | 90 | ▲ |
| Japan | 89 | ▲ |
| Malaysia | 89 | ▲ |
| Belgium (Flemish) | 89 | ▲ |
| Scotland | 88 | ▲ |
| Australia | 87 | ▲ |
| United States | 87 | ▲ |
| Hungary | 86 | ▲ |
| England | 85 | ▲ |
| Sweden | 84 | ▲ |
| Hong Kong, SAR | 84 | ▲ |
| Lithuania | 83 | ▲ |
| New Zealand | 82 | ▲ |
| Estonia | 82 | ▲ |
| Chinese Taipei | 80 | ▲ |
| Slovenia | 80 | ▲ |
| Latvia | 79 | ▲ |
| Israel | 79 | ▲ |
| Russian Federation | 79 | ▲ |
| Norway | 75 | ▲ |
| Italy | 74 | O |
| Chile | 73 | O |
| Moldova, Rep. of | 73 | O |
| Bulgaria | 71 | O |
| **International average** | **71** | |
| Lebanon | 70 | O |
| Cyprus | 68 | O |
| Slovak Republic | 68 | O |
| Romania | 67 | O |
| Botswana | 64 | ▼ |
| Macedonia, Republic of | 64 | ▼ |
| Morocco | 61 | ▼ |
| Indonesia | 61 | ▼ |
| Bahrain | 58 | ▼ |
| Iran, Islamic Republic of | 56 | ▼ |
| Armenia | 56 | ▼ |
| Serbia and Montenegro | 55 | ▼ |
| Tunisia | 55 | ▼ |
| Jordan | 54 | ▼ |
| Philippines | 52 | ▼ |
| Egypt | 51 | ▼ |
| Palestinian Nat'l Auth. | 44 | ▼ |
| Saudi Arabia | 40 | ▼ |
| South Africa | 35 | ▼ |
| Ghana | 32 | ▼ |

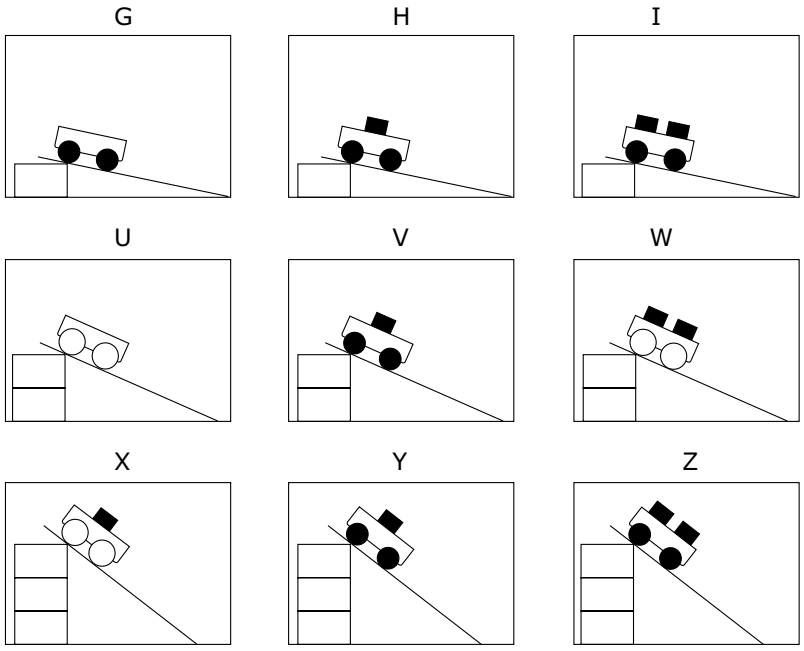
**Country average vs. International average:**

Higher ▲
Not different O
Lower ▼

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| **PHYSICS** | Forces and Motion | Reasoning and Analysis |

## Controlled experiment with cart

The diagrams show nine different trials Michael carried out using carts with wheels of two different sizes and different numbers of blocks of equal mass. He used the same ramp for all trials, starting the carts from different heights.




He wants to test this idea: The higher the ramp is placed, the faster the cart will travel at the bottom of the ramp. Which three trials should he compare?

Ⓐ G, H and I
Ⓑ I, W and Z
Ⓒ I, V and X
Ⓓ U, W and X
Ⓔ H, V and Y

*Item Number: S022222*

**Correct Response: E**

### Overall Percent Correct

| | | |
|---|---|---|
| Singapore | 79 | ▲ |
| Japan | 78 | ▲ |
| Korea, Republic of | 75 | ▲ |
| Hong Kong, SAR | 66 | ▲ |
| England | 65 | ▲ |
| Chinese Taipei | 63 | ▲ |
| Netherlands | 59 | ▲ |
| Malaysia | 58 | ▲ |
| Australia | 58 | ▲ |
| Scotland | 58 | ▲ |
| United States | 57 | ▲ |
| Hungary | 56 | ▲ |
| Lithuania | 54 | ▲ |
| New Zealand | 54 | ▲ |
| Estonia | 51 | ▲ |
| Sweden | 48 | ▲ |
| Belgium (Flemish) | 48 | ▲ |
| Russian Federation | 47 | O |
| Slovenia | 45 | O |
| Armenia | 45 | O |
| Italy | 44 | O |
| **International average** | **43** | |
| Slovak Republic | 43 | O |
| Latvia | 42 | O |
| Norway | 41 | O |
| Israel | 41 | O |
| Serbia and Montenegro | 39 | ▼ |
| Bahrain | 37 | ▼ |
| Romania | 36 | ▼ |
| Bulgaria | 36 | ▼ |
| Jordan | 35 | ▼ |
| Cyprus | 34 | ▼ |
| Chile | 33 | ▼ |
| Saudi Arabia | 32 | ▼ |
| Macedonia, Republic of | 31 | ▼ |
| Lebanon | 31 | ▼ |
| Iran, Islamic Republic of | 31 | ▼ |
| Moldova, Rep. of | 30 | ▼ |
| Philippines | 30 | ▼ |
| Palestinian Nat'l Auth. | 25 | ▼ |
| Indonesia | 25 | ▼ |
| Egypt | 23 | ▼ |
| Botswana | 23 | ▼ |
| Tunisia | 23 | ▼ |
| Morocco | 22 | ▼ |
| South Africa | 18 | ▼ |
| Ghana | 18 | ▼ |

**Country average vs. International average:**

Higher ▲
Not different O
Lower ▼

| Content Domain | Main Topic | Cognitive Domain |
|---|---|---|
| **PHYSICS** | Forces and Motion | Reasoning and Analysis |

## Data trend of masses on spring

The table below shows the results of an experiment to investigate how the length of a spring changes as different masses are hung from it.

| Mass (grams) | Length of Spring (cm) |
|---|---|
| 0 | 5 |
| 10 | 7 |
| 20 | 9 |
| 30 | 11 |
| 40 | 12 |
| 50 | 13 |
| 60 | 13 |

Describe how the length of the spring changed as different masses were hung from it.

*Item Number: S022286*

### Overall Percent Correct

| | | |
|---|---|---|
| Singapore | 75 | ▲ |
| Hungary | 73 | ▲ |
| Slovak Republic | 71 | ▲ |
| Korea, Republic of | 68 | ▲ |
| Chinese Taipei | 67 | ▲ |
| Estonia | 66 | ▲ |
| New Zealand | 65 | ▲ |
| Armenia | 65 | ▲ |
| Chile | 62 | ▲ |
| Italy | 60 | ▲ |
| Japan | 56 | ▲ |
| Norway | 56 | ▲ |
| Australia | 55 | ▲ |
| Hong Kong, SAR | 55 | ▲ |
| Serbia and Montenegro | 53 | ▲ |
| Lithuania | 52 | ▲ |
| Sweden | 50 | ▲ |
| Slovenia | 49 | ▲ |
| Latvia | 47 | O |
| Iran, Islamic Republic of | 46 | ▲ |
| United States | 45 | O |
| Netherlands | 45 | O |
| Russian Federation | 43 | O |
| Bulgaria | 42 | O |
| **International average** | **42** | |
| Israel | 41 | O |
| Moldova, Rep. of | 40 | O |
| Belgium (Flemish) | 39 | O |
| Jordan | 37 | ▼ |
| Macedonia, Republic of | 36 | ▼ |
| Romania | 36 | ▼ |
| Palestinian Nat'l Auth. | 35 | ▼ |
| Scotland | 34 | ▼ |
| Malaysia | 33 | ▼ |
| Egypt | 33 | ▼ |
| England | 30 | ▼ |
| Philippines | 29 | ▼ |
| Saudi Arabia | 27 | ▼ |
| Cyprus | 26 | ▼ |
| Lebanon | 20 | ▼ |
| Indonesia | 17 | ▼ |
| Morocco | 17 | ▼ |
| Bahrain | 13 | ▼ |
| Tunisia | 12 | ▼ |
| Botswana | 7 | ▼ |
| South Africa | 6 | ▼ |
| Ghana | 2 | ▼ |

**Country average vs. International average:**

Higher ▲
Not different O
Lower ▼

# Data trend of masses on spring (continued)

*Item Number: S022286*

## SCORING

Note: To receive credit, responses must address two basic regions in the table to describe the trend in spring length as a function of the mass added:

(i) initially, the spring increases in length (at a constant rate) as more mass is added.

(ii) after a point (40 grams), the spring length starts to level off and then remains constant as more mass is added.

Responses may be quantitative or qualitative in nature. [No credit is lost for using wrong or no units in describing length or mass.]

### Correct Response

- Response includes both regions (i) and (ii).
  *Examples: At low mass, it grew 2 for every 10 grams. Then it changed by 1 at 40g. Then at 50g, it did not grow any more.*
  *It increases by 2's until 30, increases by 1's until 50, and increases by 0 at 60.*
  *The length increased steadily up to 40g, and then it increased just a little bit more until it was 13cm at 50 and 60 grams.*
  *At first it got longer every time you added a mass, but then after a while, it did not get any longer.*
- Other correct.

### Incorrect Response

- Includes only region (i). Response references only an increase in length as more mass is added but discussion of leveling off is inadequate or missing.
  *Examples: The length increased as more mass was added.*
  *The spring length got 2cm longer with each mass.*
  *It increased by 2cm each time until 40 grams.*
- Refers only to leveling off of spring length or decreasing increments at higher masses. [Description of change in region (i) is inadequate or missing.]
  *Examples: It stretches but only up to 13 cm.*
  *After 50 grams it did not change.*
  *It stretches less at higher masses.*
- Other incorrect (including crossed out/erased, stray marks, illegible, or off task).

## Data trend of masses on spring (continued)

*Item Number: S022286*

# Student Responses

### Correct Response:

The table below shows the results of an experiment to investigate how the length of a spring changes as different masses are hung from it.

| Mass (grams) | Length of Spring (cm) |
|---|---|
| 0 | 5 |
| 10 | 7 |
| 20 | 9 |
| 30 | 11 |
| 40 | 12 |
| 50 | 13 |
| 60 | 13 |

Describe how the length of the spring changed as different masses were hung from it.

The length increased by 2 until it reached a mass of 30 grams it than increased by 1 and than sustained after a mass of 50.

## Data trend of masses on spring (continued)

*Item Number: S022286*

# Student Responses (continued)

### Incorrect Response:

The table below shows the results of an experiment to investigate how the length of a spring changes as different masses are hung from it.

| Mass (grams) | Length of Spring (cm) |
|---|---|
| 0 | 5 |
| 10 | 7 |
| 20 | 9 |
| 30 | 11 |
| 40 | 12 |
| 50 | 13 |
| 60 | 13 |

Describe how the length of the spring changed as different masses were hung from it. it got longer as you hung heavier things from it.