MASSACHUSETTS DEPARTMENT OF
ELEMENTARY AND SECONDARY
EDUCATION

Release of February 2023 MCAS Biology and Introductory Physics Test Information

April 2023
Massachusetts Department of Elementary and Secondary Education

MASSACHUSETTS DEPARTMENT OF
ELEMENTARY AND SECONDARY
EDUCATION

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I. Document Purpose and Structure

Document Purpose and Structure

Purpose

The purpose of this document is to share with educators and the public information regarding the February 2023 MCAS Biology and Introductory Physics tests, including the reporting category and standard associated with each item. The Department does not currently release items from the February Biology and Introductory Physics tests. All items continue to be released for the spring Biology and Introductory Physics tests.

Structure

Chapters II and III of this document contain, respectively, information for the February 2023 Biology and Introductory Physics tests. Each of these chapters has two sections.

The **first section** provides a brief overview of the test, including test format and item types. The Introductory Physics Reference Sheet used by students during MCAS Introductory Physics test sessions appears at the end of the first section of the Introductory Physics chapter.

The **second section** of each chapter are tables that cross-reference each item on the computer-based test and the paper-based test with its MCAS reporting category and with the *Framework* standard it assesses. The tables show how the items on the test assess standards in the 2016 *Massachusetts Science and Technology/ Engineering Curriculum Framework*.

II. February 2023 Biology Test

February 2023 High School Biology Test

The February 2023 high school Biology test was a next-generation assessment that was administered in two primary formats: a computer-based version and a paper-based version. Most students took the computer-based test. The paper-based test was offered as an accommodation for eligible students who were unable to use a computer. More information can be found on the MCAS Test Administration Resources page at www.doe.mass.edu/mcas/admin.html.

Most of the operational items on the high school Biology test were the same, regardless of whether a student took the computer-based version or the paper-based version. In places where a technology-enhanced item was used on the computer-based test, an adapted version of the item was created for use on the paper test. These adapted paper items were multiple-choice or multiple-select items that tested the same content and assessed the same standard as the technology-enhanced item.

Test Sessions

The high school Biology test was made up of two separate test sessions. Each session included selected-response questions and constructed-response questions. On the paper-based test, the selected-response questions were multiple-choice items and multiple-select items, in which students select the correct answer(s) from among several answer options.

Standards and Reporting Categories

The February 2023 high school MCAS Biology test was based on learning standards in the 2016 *Massachusetts Science and Technology/Engineering Curriculum Framework*. The Framework is available on the Department website at www.doe.mass.edu/frameworks/current.html.

The biology standards are grouped under the four content reporting categories listed below.

- Molecules to Organisms
- Heredity
- Evolution
- Ecosystems

Most items on the high school Biology test are also reported as aligning to one of three MCAS Science Practice Categories. The three practice categories are listed below.

- Practice Category A: Investigations and Questioning
- Practice Category B: Mathematics and Data
- Practice Category C: Evidence, Reasoning, and Modeling

More information about the practice categories is available on the Department website at www.doe.mass.edu/mcas/tdd/practice-categories.html.

The tables at the conclusion of this chapter provides the following information about each released operational item: reporting category, standard covered, science practice category covered (if any), item type, and item description.

Spanish-Language Edition

Since approximately 55% of English learner students in Massachusetts public schools are native Spanish speakers, a Spanish-language edition of the February Biology test was made available to eligible Spanish-speaking students. The computer-based version of the Spanish-language edition presented the Spanish translation above the English text for each item. The booklets for the paper-based version of the Spanish-language edition were issued in side-by-side English/Spanish format: pages on the left side of each booklet presented items in Spanish; pages on the right side presented the same items in English.

Reference Materials and Tools

Each student taking the high school Biology test had access to a calculator.

During both Biology test sessions, the use of bilingual word-to-word dictionaries was allowed for current and former English learner students only.

February 2023 Biology
Computer-Based Operational Items

CBT Item No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description
1	*Molecules to Organisms*	HS.LS.1.5	B. Mathematics and Data	SR	Identify how inputs or outputs of photosynthesis will change with increases in atmospheric carbon dioxide.
2	*Ecology*	HS.LS.2.4	B. Mathematics and Data	SR	Calculate the available energy at a certain trophic level.
3	*Molecules to Organisms*	HS.LS.1.6	C. Evidence, Reasoning, and Modeling	SR	Describe the function of an organic molecule based on its molecular structure.
4	*Molecules to Organisms*	HS.LS.1.2	None	SR	Identify the blood vessels involved in the exchange of nutrients and wastes with body cells.
5	*Heredity*	HS.LS.3.4	None	SR	Identify a type of inheritance pattern based on given information.
6	*Molecules to Organisms*	HS.LS.1.1	C. Evidence, Reasoning, and Modeling	SR	Determine the sequence of mRNA codons and amino acids for a given a DNA sequence.
7	*Molecules to Organisms*	HS.LS.1.3	C. Evidence, Reasoning, and Modeling	SR	Analyze a model to describe the purpose of a feedback loop.
8	*Ecology*	HS.LS.2.5	None	SR	Explain how carbon dioxide can be traced from air to a plant, and then to a primary consumer.
9	*Molecules to Organisms*	HS.LS.1.7	C. Evidence, Reasoning, and Modeling	SR	Complete a model of cellular respiration and describe how the products are used in the cell.
10	*Evolution*	HS.LS.4.1	C. Evidence, Reasoning, and Modeling	SR	Analyze information to draw conclusions about the evolutionary relationship between a fossilized plant and plants living today.
11	*Evolution*	HS.LS.4.4	None	SR	Describe how a virus reproduces in a cell.
12	*Heredity*	HS.LS.3.3	C. Evidence, Reasoning, and Modeling	SR	Analyze information about parental phenotypes to identify the set up of a Punnett square.
13	*Evolution*	HS.LS.4.4	None	SR	Explain why viruses can spread quickly in a population.
14	*Molecules to Organisms*	HS.LS.1.1	None	SR	Identify the type of organic molecule that results from the expression of genes.
15	*Heredity*	HS.LS.3.1	None	SR	Describe the type of cells produced by meiosis and explain why meiosis must occur before fertilization.
16	*Heredity*	HS.LS.3.3	C. Evidence, Reasoning, and Modeling	CR	Calculate the percentage of phenotypes produced by different genetic crosses and explain which genetic cross would provide evidence for the segregation of alleles during meiosis.
17	*Molecules to Organisms*	HS.LS.1.7	None	SR	Explain why a certain type of cell would be expected to have the most mitochondria.
18	*Molecules to Organisms*	HS.LS.1.6	None	SR	Describe a similarity shared by all organic molecules.
19	*Heredity*	HS.LS.3.2	C. Evidence, Reasoning, and Modeling	SR	Describe how a genetic mutation can occur and identify which type of cell the mutation must occur in for it to be inherited by an offspring.
20	*Molecules to Organisms*	HS.LS.1.4	C. Evidence, Reasoning, and Modeling	CR	Explain how cell division repairs damaged tissue, identify the process DNA undergoes prior to mitosis, describe a step of a model of mitosis, and explain why the step is important.
21	*Evolution*	HS.LS.4.5	C. Evidence, Reasoning, and Modeling	CR	Explain how geographic isolation affects gene pools between two populations, identify evidence that could be used to support whether two populations are different species, and explain how the evidence could be used.

CBT Item No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description
22	*Molecules to Organisms*	HS.LS.1.6	None	SR	Classify a molecule as a carbohydrate and describe its function.
23	*Heredity*	HS.LS.3.2	C. Evidence, Reasoning, and Modeling	SR	Analyze information from an investigation to explain the cause of genetic variation in a population.
24	*Molecules to Organisms*	HS.LS.1.2	None	SR	Describe how information moves through the nervous system.
25	*Ecology*	HS.LS.2.1	B. Mathematics and Data	SR	Use a food web to identify ecological relationships and to calculate the amount of energy available to secondary consumers.
26	*Molecules to Organisms*	HS.LS.1.5	A. Investigations and Questioning	SR	Identify an experimental condition that would result in the lowest carbon dioxide level.
27	*Heredity*	HS.LS.3.2	None	SR	Explain why a DNA mutation did not change the protein produced by the mutated gene.
28	*Molecules to Organisms*	HS.LS.1.3	None	SR	Describe how homeostasis is restored in a feedback loop.
29	*Ecology*	HS.LS.2.4	C. Evidence, Reasoning, and Modeling	SR	Identify the ecological role of an organism based on a food web.
30	*Heredity*	HS.LS.3.4	C. Evidence, Reasoning, and Modeling	SR	Describe how certain conditions are influenced by the interaction of genetics and the environment.
31	*Evolution*	HS.LS.4.1	None	SR	Identify a limitation of using the fossil record to answer some questions about extinct organisms.
32	*Heredity*	HS.LS.3.2	C. Evidence, Reasoning, and Modeling	SR	Describe how a trait can be inherited when neither parent displays the trait.
33	*Evolution*	HS.LS.4.5	C. Evidence, Reasoning, and Modeling	SR	Use evidence to support a claim that a bottleneck event occurred in a population's gene pool.
34	*Ecology*	HS.LS.2.1	None	SR	Identify the ecological relationship between two species in an ecosystem.
35	*Heredity*	HS.LS.3.1	None	SR	Identify the process that produces gametes.
36	*Molecules to Organisms*	HS.LS.1.7	C. Evidence, Reasoning, and Modeling	SR	Explain how the number of mitochondria in a tissue impacts the rate of cellular respiration and determine cellular respiration inputs.
37	*Evolution*	HS.LS.4.2	C. Evidence, Reasoning, and Modeling	CR	Identify how an adaptation can become part of the gene pool and explain how that adaptation can become more common in the population over time.
38	*Ecology*	HS.LS.2.5	None	SR	Identify a carbon cycle process that moves carbon in an ecosystem.
39	*Molecules to Organisms*	HS.LS.1.2	C. Evidence, Reasoning, and Modeling	SR	Analyze information to determine which digestive organs from two types of organisms share the same function.
40	*Ecology*	HS.LS.2.1	C. Evidence, Reasoning, and Modeling	SR	Use a food web to describe how a change in the population size of one species would affect other populations within the ecosystem.
41	*Heredity*	HS.LS.3.1	C. Evidence, Reasoning, and Modeling	SR	Complete a model to show the products of meiosis and identify processes that increase a population's genetic variability.
42	*Ecology*	HS.LS.2.7	None	CR	Use evidence to describe the characteristics of an invasive species, describe its affect on ecosystem biodiversity, and evaluate strategies for controlling an invasive species.

*Science and Technology/Engineering item types are: selected-response (SR) and constructed-response (CR).

February 2023 Biology
Paper-Based Operational Items

PBT Item No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description
1	*Molecules to Organisms*	HS.LS.1.5	B. Mathematics and Data	SR	Identify how inputs or outputs of photosynthesis will change with increases in atmospheric carbon dioxide.
2	*Ecology*	HS.LS.2.4	B. Mathematics and Data	SR	Calculate the available energy at a certain trophic level.
3	*Molecules to Organisms*	HS.LS.1.6	C. Evidence, Reasoning, and Modeling	SR	Describe the function of an organic molecule based on its molecular structure.
4	*Molecules to Organisms*	HS.LS.1.2	None	SR	Identify the blood vessels involved in the exchange of nutrients and wastes with body cells.
5	*Heredity*	HS.LS.3.4	None	SR	Identify a type of inheritance pattern based on given information.
6	*Molecules to Organisms*	HS.LS.1.1	C. Evidence, Reasoning, and Modeling	SR	Determine the sequence of mRNA codons and amino acids for a given a DNA sequence.
7	*Molecules to Organisms*	HS.LS.1.3	C. Evidence, Reasoning, and Modeling	SR	Analyze a model to describe the purpose of a feedback loop.
8	*Ecology*	HS.LS.2.5	None	SR	Explain how carbon dioxide can be traced from air to a plant, and then to a primary consumer.
9	*Molecules to Organisms*	HS.LS.1.7	C. Evidence, Reasoning, and Modeling	SR	Complete a model of cellular respiration and describe how the products are used in the cell.
10	*Evolution*	HS.LS.4.1	C. Evidence, Reasoning, and Modeling	SR	Analyze information to draw conclusions about the evolutionary relationship between a fossilized plant and plants living today.
11	*Evolution*	HS.LS.4.4	None	SR	Describe how a virus reproduces in a cell.
12	*Heredity*	HS.LS.3.3	C. Evidence, Reasoning, and Modeling	SR	Analyze information about parental phenotypes to identify the set up of a Punnett square.
13	*Evolution*	HS.LS.4.4	None	SR	Explain why viruses can spread quickly in a population.
14	*Molecules to Organisms*	HS.LS.1.1	None	SR	Identify the type of organic molecule that results from the expression of genes.
15	*Heredity*	HS.LS.3.1	None	SR	Describe the type of cells produced by meiosis and explain why meiosis must occur before fertilization.
16	*Heredity*	HS.LS.3.3	C. Evidence, Reasoning, and Modeling	CR	Calculate the percentage of phenotypes produced by different genetic crosses and explain which genetic cross would provide evidence for the segregation of alleles during meiosis.
17	*Molecules to Organisms*	HS.LS.1.7	None	SR	Explain why a certain type of cell would be expected to have the most mitochondria.
18	*Molecules to Organisms*	HS.LS.1.6	None	SR	Describe a similarity shared by all organic molecules.
19	*Heredity*	HS.LS.3.2	C. Evidence, Reasoning, and Modeling	SR	Describe how a genetic mutation can occur and identify which type of cell the mutation must occur in for it to be inherited by an offspring.
20	*Molecules to Organisms*	HS.LS.1.4	C. Evidence, Reasoning, and Modeling	CR	Explain how cell division repairs damaged tissue, identify the process DNA undergoes prior to mitosis, describe a step of a model of mitosis, and explain why the step is important.
21	*Evolution*	HS.LS.4.5	C. Evidence, Reasoning, and Modeling	CR	Explain how geographic isolation affects gene pools between two populations, identify evidence that could be used to support whether two populations are different species, and explain how the evidence could be used.

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23	*Heredity*	HS.LS.3.2	C. Evidence, Reasoning, and Modeling	SR	Analyze information from an investigation to explain the cause of genetic variation in a population.
24	*Molecules to Organisms*	HS.LS.1.2	None	SR	Describe how information moves through the nervous system.
25	*Ecology*	HS.LS.2.1	B. Mathematics and Data	SR	Use a food web to identify ecological relationships and to calculate the amount of energy available to secondary consumers.
26	*Molecules to Organisms*	HS.LS.1.5	A. Investigations and Questioning	SR	Identify an experimental condition that would result in the lowest carbon dioxide level.
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28	*Molecules to Organisms*	HS.LS.1.3	None	SR	Describe how homeostasis is restored in a feedback loop.
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* Science and Technology/Engineering item types are: selected-response (SR) and constructed-response (CR).

III. February 2023 Introductory Physics Test

February 2023 High School Introductory Physics Test

The February 2023 high school Introductory Physics test was a next-generation assessment that was administered in two primary formats: a computer-based version and a paper-based version. Most students took the computer-based test. The paper-based test was offered as an accommodation for eligible students who were unable to use a computer. More information can be found on the MCAS Test Administration Resources page at www.doe.mass.edu/mcas/admin.html.

Most of the operational items on the high school Introductory Physics test were the same, regardless of whether a student took the computer-based version or the paper-based version. In places where a technology-enhanced item was used on the computer-based test, an adapted version of the item was created for use on the paper test. These adapted paper items were multiple-choice or multiple-select items that tested the same content and assessed the same standard as the technology-enhanced item.

Test Sessions

The high school Introductory Physics test was made up of two separate test sessions. Each session included selected-response questions and constructed-response questions. On the paper-based test, the selected-response questions were multiple-choice items and multiple-select items, in which students select the correct answer(s) from among several answer options.

Standards and Reporting Categories

The February 2023 high school Introductory Physics test was based on learning standards in the 2016 *Massachusetts Science and Technology/Engineering Curriculum Framework*. The Framework is available on the Department website at www.doe.mass.edu/frameworks/current.html.

The introductory physics standards are grouped under the three content reporting categories listed below. Note that standard HS.PHY.1.8 is included in the Energy reporting category.

- Motion, Forces, and Interactions
- Energy
- Waves

Most items on the high school Introductory Physics test are also reported as aligning to one of three MCAS Science Practice Categories. The three practice categories are listed below.

- Practice Category A: Investigations and Questioning
- Practice Category B: Mathematics and Data
- Practice Category C: Evidence, Reasoning, and Modeling

More information about the practice categories is available on the Department website at www.doe.mass.edu/mcas/tdd/practice-categories.html.

The tables at the conclusion of this chapter provides the following information about each released operational item: reporting category, standard covered, science practice category covered (if any), item type, and item description.

Spanish-Language Edition

Since approximately 55% of English learner students in Massachusetts public schools are native Spanish speakers, a Spanish-language edition of the February Introductory Physics test was made available to eligible Spanish-speaking students. The computer-based version of the Spanish-language edition presented the Spanish translation above the English text for each item. The booklets for the paper-based version of the Spanish-language edition were issued in side-by-side English/Spanish format: pages on the left side of each booklet presented items in Spanish; pages on the right side presented the same items in English.

Reference Materials

Each student taking the high school Introductory Physics test had access to the MCAS Introductory Physics Reference Sheet. A copy of the reference sheet is provided on the next page. Each student also had access to a calculator.

During both high school Introductory Physics test sessions, the use of bilingual word-to-word dictionaries was allowed for current and former English learner students only.

MASSACHUSETTS DEPARTMENT OF ELEMENTARY AND SECONDARY EDUCATION

Massachusetts Comprehensive Assessment System
Introductory Physics Reference Sheet

Formulas

$s_{average} = \frac{d}{\Delta t}$

$v_{average} = \frac{\Delta x}{\Delta t}$

$a_{average} = \frac{\Delta v}{\Delta t}$

$v_f = v_i + a\Delta t$

$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$

$p = mv$

$F\Delta t = \Delta p$

$F_{net} = ma$

$F_g = mg$

$F_g = G\frac{m_1 m_2}{d^2}$

$F_e = k\frac{q_1 q_2}{d^2}$

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

$\Delta PE = mg\Delta h$

$W = \Delta E = Fd$

$eff = \frac{E_{out}}{E_{in}}$

$Q = mc\Delta T$

$v = \lambda f$

$T = \frac{1}{f}$

$V = IR$

Variables

a = acceleration
c = specific heat
d = distance
E = energy
eff = efficiency
f = frequency
F = force
g = acceleration due to gravity
Δh = change in height
I = current
KE = kinetic energy
λ = wavelength
m = mass
p = momentum
ΔPE = change in gravitational potential energy
q = charge of particle
Q = heat added or removed
R = resistance
s = speed
Δt = change in time
T = period
ΔT = change in temperature
v = velocity
V = potential difference (voltage)
W = work
Δx = change in position (displacement)

Unit Symbols

ampere, A
coulomb, C
degree Celsius, °C
hertz, Hz
joule, J
kilogram, kg
meter, m
newton, N
ohm, Ω
second, s
volt, V

Definitions

speed of electromagnetic waves in a vacuum = 3×10^8 m/s

G = Universal gravitational constant = $6.7 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$

k = Coulomb's constant = $9 \times 10^9 \frac{N \cdot m^2}{C^2}$

$g \approx 10$ m/s^2 at Earth's surface

$1\ N = 1\frac{kg \cdot m}{s^2}$

$1\ J = 1\ N \cdot m$

Updated June 2018

February 2023 Introductory Physics
Computer-Based Operational Items

CBT Item No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description
1	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Interpret a velocity vs. time graph to identify when the net force on an object is zero.
2	*Energy*	HS.PHY.3.4	None	SR	Describe how the procedure of an investigation about heating a liquid should be changed.
3	*Energy*	HS.PHY.3.3	C. Evidence, Reasoning, and Modeling	SR	Describe an energy conversion that takes place within a system.
4	*Motion, Forces, and Interactions*	HS.PHY.2.9	C. Evidence, Reasoning, and Modeling	SR	Determine the total resistance in a series circuit.
5	*Motion, Forces, and Interactions*	HS.PHY.2.3	C. Evidence, Reasoning, and Modeling	SR	Determine which model best represents the forces between two colliding objects.
6	*Motion, Forces, and Interactions*	HS.PHY.2.9	C. Evidence, Reasoning, and Modeling	SR	Complete a model of a series circuit, given design constraints, and compare the current through two circuit elements in a parallel circuit.
7	*Energy*	HS.PHY.1.8	None	SR	Identify a similarity between two nuclear processes.
8	*Energy*	HS.PHY.3.5	C. Evidence, Reasoning, and Modeling	SR	Describe how the force and energy between two magnets change when the magnets are moved closer together.
9	*Motion, Forces, and Interactions*	HS.PHY.2.9	C. Evidence, Reasoning, and Modeling	SR	Complete a model of a parallel circuit with a given total current.
10	*Motion, Forces, and Interactions*	HS.PHY.2.1	B. Mathematics and Data	SR	Calculate the acceleration of an object.
11	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Analyze a position vs. time graph to determine the velocity of an object.
12	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Interpret a model to determine the net force on an object.
13	*Energy*	HS.PHY.3.1	B. Mathematics and Data	SR	Analyze a diagram to determine the distance an object moved and then calculate the work done on the object.
14	*Motion, Forces, and Interactions*	HS.PHY.2.3	C. Evidence, Reasoning, and Modeling	SR	Compare the velocities and momentums of two objects that were accelerated with the same amount of force.
15	*Motion, Forces, and Interactions*	HS.PHY.2.2	B. Mathematics and Data	SR	Calculate the velocity of an object after a collision using conservation of momentum.
16	*Motion, Forces, and Interactions*	HS.PHY.2.10	B. Mathematics and Data	CR	Calculate the average acceleration of a sliding object, the force of friction acting on the object, and how far the object would have traveled if it had been on a frictionless surface.
17	*Motion, Forces, and Interactions*	HS.PHY.2.4	B. Mathematics and Data	SR	Identify the relationship between electrostatic force and charge.
18	*Energy*	HS.PHY.3.3	B. Mathematics and Data	SR	Calculate the percent efficiency of a device.
19	*Motion, Forces, and Interactions*	HS.PHY.2.5	None	SR	Describe how an electric current can be produced using a magnet.
20	*Energy*	HS.PHY.3.4	B. Mathematics and Data	CR	Compare the amount of thermal energy absorbed by different objects when given the objects' mass and specific heat and explain the reasoning; determine the material of an unknown object after calculating its specific heat.

CBT Item No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description
21	*Motion, Forces, and Interactions*	HS.PHY.2.4	B. Mathematics and Data	CR	Analyze models of pairs of charges to compare the forces between them, and determine if there would be a net force on a test charge placed between the charges in each pair and explain the reasoning.
22	*Energy*	HS.PHY.3.1	B. Mathematics and Data	SR	Calculate the minimum amount of work done on an object.
23	*Motion, Forces, and Interactions*	HS.PHY.2.9	C. Evidence, Reasoning, and Modeling	SR	Compare the voltage drop across two resistors in a series circuit.
24	*Energy*	HS.PHY.3.5	C. Evidence, Reasoning, and Modeling	SR	Describe how the distance and electric force between two positive charges change over time.
25	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Analyze a velocity vs. time graph for an object to determine which free-body force diagram represents the forces acting on the object at different times.
26	*Motion, Forces, and Interactions*	HS.PHY.2.1	C. Evidence, Reasoning, and Modeling	SR	Interpret a position vs. time graph to describe the motion of an object.
27	*Waves*	HS.PHY.4.1	B. Mathematics and Data	SR	Calculate the wavelength of a sound.
28	*Motion, Forces, and Interactions*	HS.PHY.2.5	None	SR	Explain why a force is created between two wires that are carrying current.
29	*Motion, Forces, and Interactions*	HS.PHY.2.2	B. Mathematics and Data	SR	Determine the momentum of a system after a collision.
30	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Analyze a model to determine the net force on an object.
31	*Energy*	HS.PHY.3.4	None	SR	Describe the flow of thermal energy between two objects.
32	*Motion, Forces, and Interactions*	HS.PHY.2.2	B. Mathematics and Data	SR	Analyze a velocity vs. time graph to determine the momentum of an object.
33	*Waves*	HS.PHY.4.1	None	SR	Explain why a light wave reaches an observer sooner than a sound wave.
34	*Waves*	HS.PHY.4.1	C. Evidence, Reasoning, and Modeling	SR	Compare the wavelengths of two sound waves with different frequencies.
35	*Waves*	HS.PHY.4.5	None	SR	Identify that sound waves have longitudinal wave motion and how sound waves are interfering for a given scenario.
36	*Waves*	HS.PHY.4.3	C. Evidence, Reasoning, and Modeling	SR	Compare the frequencies and photon energies of different light sources.
37	*Waves*	HS.PHY.4.1	B. Mathematics and Data	CR	Calculate the period and wavelength of a sound wave and identify the wavelength of the sound wave in a model.
38	*Energy*	HS.PHY.3.2	None	SR	Interpret temperature data to determine the phase of a substance.
39	*Waves*	HS.PHY.4.5	None	SR	Describe what happens when a light wave travels from one medium to another.
40	*Motion, Forces, and Interactions*	HS.PHY.2.4	None	SR	Describe a difference between electrostatic and gravitational forces.
41	*Waves*	HS.PHY.4.3	C. Evidence, Reasoning, and Modeling	SR	Interpret the results from an investigation involving wave interference.
42	*Energy*	HS.PHY.3.1	B. Mathematics and Data	CR	Calculate the gravitational potential energy, kinetic energy, and velocity of an object using conservation of mechanical energy and then explain why the actual velocity of the object is different than the calculated value.

* Science and Technology/Engineering item types are: selected-response (SR) and constructed-response (CR).

February 2023 Introductory Physics
Paper-Based Operational Items

PBT Item No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description
1	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Interpret a velocity vs. time graph to identify when the net force on an object is zero.
2	*Energy*	HS.PHY.3.4	None	SR	Describe how the procedure of an investigation about heating a liquid should be changed.
3	*Energy*	HS.PHY.3.3	C. Evidence, Reasoning, and Modeling	SR	Describe an energy conversion that takes place within a system.
4	*Motion, Forces, and Interactions*	HS.PHY.2.9	C. Evidence, Reasoning, and Modeling	SR	Determine the total resistance in a series circuit.
5	*Motion, Forces, and Interactions*	HS.PHY.2.3	C. Evidence, Reasoning, and Modeling	SR	Determine which model best represents the forces between two colliding objects.
6	*Motion, Forces, and Interactions*	HS.PHY.2.9	C. Evidence, Reasoning, and Modeling	SR	Determine which series circuit has a given current and compare the current through two circuit elements in a parallel circuit.
7	*Energy*	HS.PHY.1.8	None	SR	Identify a similarity between two nuclear processes.
8	*Energy*	HS.PHY.3.5	C. Evidence, Reasoning, and Modeling	SR	Describe how the force and energy between two magnets change when the magnets are moved closer together.
9	*Motion, Forces, and Interactions*	HS.PHY.2.9	C. Evidence, Reasoning, and Modeling	SR	Determine which parallel circuit has a given total current.
10	*Motion, Forces, and Interactions*	HS.PHY.2.1	B. Mathematics and Data	SR	Calculate the acceleration of an object.
11	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Analyze a position vs. time graph to determine the velocity of an object.
12	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Interpret a model to determine the net force on an object.
13	*Energy*	HS.PHY.3.1	B. Mathematics and Data	SR	Analyze a diagram to determine the distance an object moved and then calculate the work done on the object.
14	*Motion, Forces, and Interactions*	HS.PHY.2.3	C. Evidence, Reasoning, and Modeling	SR	Compare the velocities and momentums of two objects that were accelerated with the same amount of force.
15	*Motion, Forces, and Interactions*	HS.PHY.2.2	B. Mathematics and Data	SR	Calculate the velocity of an object after a collision using conservation of momentum.
16	*Motion, Forces, and Interactions*	HS.PHY.2.10	B. Mathematics and Data	CR	Calculate the average acceleration of a sliding object, the force of friction acting on the object, and how far the object would have traveled if it had been on a frictionless surface.
17	*Motion, Forces, and Interactions*	HS.PHY.2.4	B. Mathematics and Data	SR	Identify the relationship between electrostatic force and charge.
18	*Energy*	HS.PHY.3.3	B. Mathematics and Data	SR	Calculate the percent efficiency of a device.
19	*Motion, Forces, and Interactions*	HS.PHY.2.5	None	SR	Describe how an electric current can be produced using a magnet.
20	*Energy*	HS.PHY.3.4	B. Mathematics and Data	CR	Compare the amount of thermal energy absorbed by different objects when given the objects' mass and specific heat and explain the reasoning; determine the material of an unknown object after calculating its specific heat.

PBT Item No.	Reporting Category	Standard	Science Practice Category	Item Type*	Item Description
21	*Motion, Forces, and Interactions*	HS.PHY.2.4	B. Mathematics and Data	CR	Analyze models of pairs of charges to compare the forces between them, and determine if there would be a net force on a test charge placed between the charges in each pair and explain the reasoning.
22	*Energy*	HS.PHY.3.1	B. Mathematics and Data	SR	Calculate the minimum amount of work done on an object.
23	*Motion, Forces, and Interactions*	HS.PHY.2.9	C. Evidence, Reasoning, and Modeling	SR	Compare the voltage drop across two resistors in a series circuit.
24	*Energy*	HS.PHY.3.5	C. Evidence, Reasoning, and Modeling	SR	Describe how the distance and electric force between two positive charges change over time.
25	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Analyze a velocity vs. time graph for an object to determine which free-body force diagram represents the forces acting on the object at different times.
26	*Motion, Forces, and Interactions*	HS.PHY.2.1	C. Evidence, Reasoning, and Modeling	SR	Interpret a position vs. time graph to describe the motion of an object.
27	*Waves*	HS.PHY.4.1	B. Mathematics and Data	SR	Calculate the wavelength of a sound.
28	*Motion, Forces, and Interactions*	HS.PHY.2.5	None	SR	Explain why a force is created between two wires that are carrying current.
29	*Motion, Forces, and Interactions*	HS.PHY.2.2	B. Mathematics and Data	SR	Determine the momentum of a system after a collision.
30	*Motion, Forces, and Interactions*	HS.PHY.2.10	C. Evidence, Reasoning, and Modeling	SR	Analyze a model to determine the net force on an object.
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