

MCAS High School Introductory Physics
Computer-Based Practice Test Answer Key

Session 1

Item Number	Reporting Category	Standard	Science Practice Category	Item Type*	Max Points	Correct Answer**
1	Waves	HS-PS4-1	B. Mathematics and Data	SR	1	B
2	Energy	HS-PS3-5	C. Evidence, Reasoning, and Modeling	SR	1	see page 3
3	Motion, Forces, and Interactions	HS-PS2-2	B. Mathematics and Data	SR	1	B
4	Motion, Forces, and Interactions	HS-PS2-1	C. Evidence, Reasoning, and Modeling	SR	1	D
5	Motion, Forces, and Interactions	HS-PS2-4	B. Mathematics and Data	SR	1	C
6	Motion, Forces, and Interactions	HS-PS2-9(MA)	C. Evidence, Reasoning, and Modeling	SR	1	see page 3
7	Waves	HS-PS4-5	C. Evidence, Reasoning, and Modeling	SR	2	Part A: A Part B: see page 3
8	Motion, Forces, and Interactions	HS-PS2-3	A. Investigations and Questioning	SR	1	A, D
9	Energy	HS-PS1-8	C. Evidence, Reasoning, and Modeling	SR	1	see page 3
10	Energy	HS-PS3-1	C. Evidence, Reasoning, and Modeling	SR	2	Part A: D Part B: see page 3
11	Energy	HS-PS3-1	B. Mathematics and Data	SR	1	A
12	Motion, Forces, and Interactions	HS-PS2-9(MA)	B. Mathematics and Data	SR	1	A
13	Motion, Forces, and Interactions	HS-PS2-4	None	SR	1	B
14	Motion, Forces, and Interactions	HS-PS2-2	B. Mathematics and Data	SR	1	B
15	Motion, Forces, and Interactions	HS-PS2-10 (MA)	C. Evidence, Reasoning, and Modeling	SR	1	C
16	Energy	HS-PS3-1	C. Evidence, Reasoning, and Modeling	SR	1	see page 4
17	Motion, Forces, and Interactions	HS-PS2-1	B. Mathematics and Data	CR	3	see pages 6–7
18	Waves	HS-PS4-3	C. Evidence, Reasoning, and Modeling	SR	1	B, C
19	Energy	HS-PS3-2	C. Evidence, Reasoning, and Modeling	SR	1	C
20	Waves	HS-PS4-1	B. Mathematics and Data	CR	4	see pages 8–9
21	Motion, Forces, and Interactions	HS-PS2-10(MA)	C. Evidence, Reasoning, and Modeling	CR	4	see pages 10–12

* Science item types are selected-response (SR) and constructed-response (CR).

**Pages 3–5 of this document provide correct answers for technology-enhanced items and pages 6–17 provide sample student responses to constructed-response items.

Session 2

Item Number	Reporting Category	Standard	Science Practice Category	Item Type	Max Points	Correct Answer*
22	Motion, Forces, and Interactions	HS-PS2-1	B. Mathematics and Data	SR	1	C
23	Energy	HS-PS1-8	C. Evidence, Reasoning, and Modeling	SR	1	C
24	Motion, Forces, and Interactions	HS-PS2-2	None	SR	1	A
25	Waves	HS-PS4-5	C. Evidence, Reasoning, and Modeling	SR	2	Part A: B Part B: C
26	Energy	HS-PS3-3	C. Evidence, Reasoning, and Modeling	SR	1	D
27	Motion, Forces, and Interactions	HS-PS2-10(MA)	B. Mathematics and Data	SR	1	B
28	Motion, Forces, and Interactions	HS-PS2-9(MA)	B. Mathematics and Data	SR	1	B
29	Motion, Forces, and Interactions	HS-PS2-4	C. Evidence, Reasoning, and Modeling	SR	1	see page 4
30	Energy	HS-PS3-3	B. Mathematics and Data	SR	1	D
31	Motion, Forces, and Interactions	HS-PS2-5	A. Investigations and Questioning	SR	2	Part A: see page 4 Part B: C
32	Waves	HS-PS4-1	C. Evidence, Reasoning, and Modeling	SR	1	D
33	Motion, Forces, and Interactions	HS-PS2-9(MA)	C. Evidence, Reasoning, and Modeling	SR	1	B
34	Waves	HS-PS4-3	None	SR	1	A
35	Energy	HS-PS3-4a	B. Mathematics and Data	SR	1	see page 5
36	Energy	HS-PS3-4a	C. Evidence, Reasoning, and Modeling	SR	1	D
37	Energy	HS-PS3-4a	B. Mathematics and Data	SR	1	C
38	Energy	HS-PS3-2	C. Evidence, Reasoning, and Modeling	CR	3	see pages 13–14
39	Motion, Forces, and Interactions	HS-PS2-10(MA)	C. Evidence, Reasoning, and Modeling	SR	1	A
40	Energy	HS-PS3-5	C. Evidence, Reasoning, and Modeling	SR	1	see page 5
41	Energy	HS-PS3-1	B. Mathematics and Data	SR	1	see page 5
42	Motion, Forces, and Interactions	HS-PS2-4	B. Mathematics and Data	SR	1	B
43	Motion, Forces, and Interactions	HS-PS2-3	A. Investigations and Questioning	CR	4	see pages 15–17

* Science item types are selected-response (SR) and constructed-response (CR).

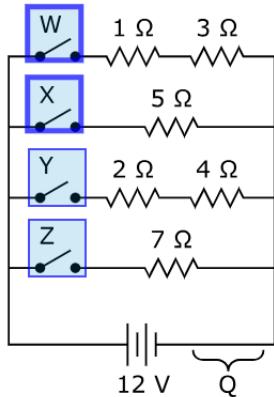
**Pages 3–5 of this document provide correct answers for technology-enhanced items and pages 6–17 provide sample student responses to constructed-response items.

Technology-Enhanced Item Keys

Correct Answer for CBT Item #2

Characteristic	Increase	Decrease
distance between the charges	<input checked="" type="radio"/>	<input type="radio"/>
electric forces between the charges	<input type="radio"/>	<input checked="" type="radio"/>

Correct Answer for CBT Item #6



Correct Answer for CBT Item #7 Part B

The path of the light from the candle appeared to bend as it traveled to the observer. As the light from the candle entered the magnifying glass, the light slowed down. Because the frequency of the light did not change, the wavelength of the light decreased.

Correct Answer for CBT Item #9

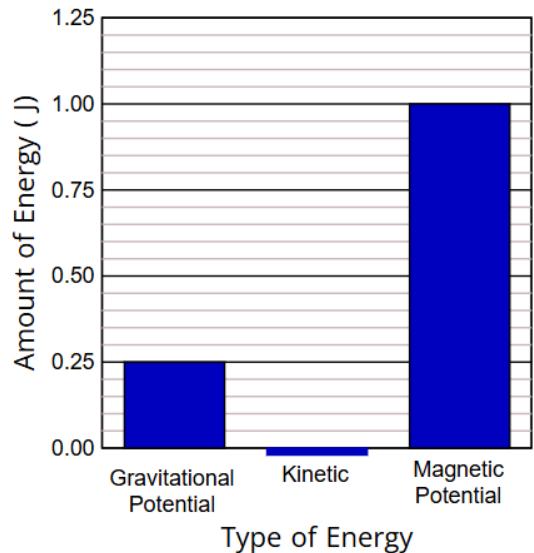
When an atomic nucleus splits into fragments, a nuclear fission process has occurred. The fragments initially have kinetic energy, which is transferred to the surrounding medium as thermal energy.

Correct Answer for CBT Item #10 Part B

As the cat was moving to the 1.1 m platform, the gravitational potential energy of the cat decreased and the kinetic energy of the cat increased.

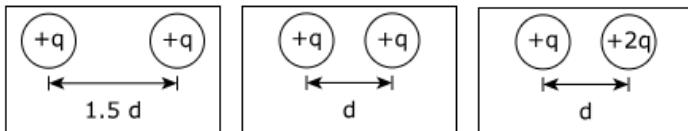
Correct Answer for CBT Item #16

Energy When Carts Were Closest Together



Correct Answer for CBT Item #29

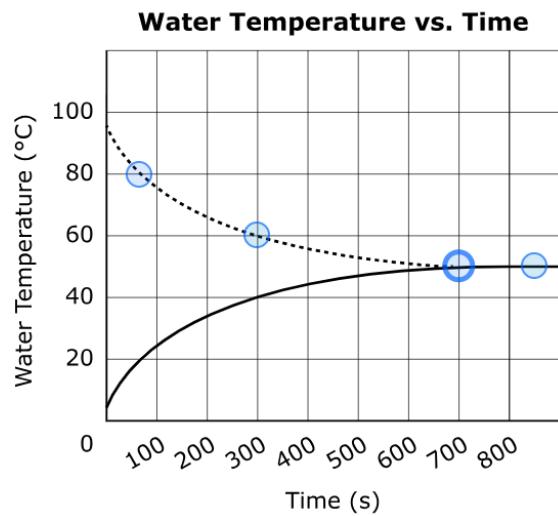
Least force \longrightarrow Greatest force



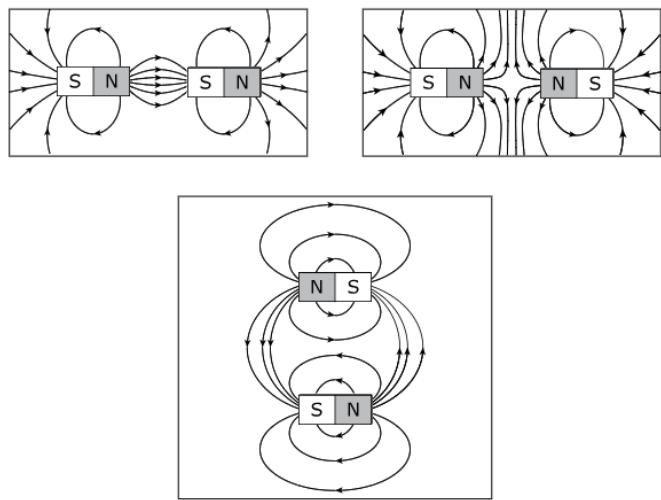
Correct Answer for CBT Item #31 Part A

The upward force that acted on the paper clips was from
a magnetic field that was generated by the
current flowing through the wire.

Correct Answer for CBT Item #35



Correct Answer for CBT Item #40



Correct Answer for CBT Item #41

Position	Gravitational Potential Energy (J)	Kinetic Energy (J)
A	20	0
B	15	5
C	0	20

Sample Student Responses for Constructed-Response Items

Item 17 Sample Student Work and Scoring Guide

Scoring Guide

Score	Description
3	The response demonstrates a thorough understanding of how to analyze the forces that act on objects during collisions and how these forces affect the motion of each object. The response correctly compares the forces between carts X and Y and explains the answer. The response also correctly calculates the acceleration of cart X and the force on cart X during the collision.
2	The response demonstrates a partial understanding of how to analyze the forces that act on objects during collisions and how these forces affect the motion of each object.
1	The response demonstrates a minimal understanding of how to analyze the forces that act on objects during collisions and how these forces affect the motion of each object.
0	The response is incorrect or contains some correct work that is irrelevant to the skill or concept being measured.

Score Point 3

Part	Student Response
A	They are the same because of Newton's 3 rd law: for every action there is an equal and opposite reaction.
B	$a = \Delta v / \Delta t$ $a = -4 / 0.1$ $a = -4 \text{ m/s}^2$
C	$f = ma$ $f = 0.5 \times (-4)$ $f = -2 \text{ newtons}$

Score Point 2

Part	Student Response
A	X and Y exerted the forces of the same magnitude on each other as according to Newton's 3 rd law which states that for every action there is an equal and opposite reaction.
B	$vf = vi + a\Delta t$ $(vf - vi) / t = a$ $(0.2 - 0.6) / 0.1 = a$ $a = -4 \text{ m/s}^2$
C	$f = ma$ $f = 0.5 \times (-4)$ $f = -2 \text{ N}$

Score Point 1

Part	Student Response
A	The magnitude of the forces that cart X and cart Y exerted on each other during the collision were different because cart Y was not moving but cart X was so Cart X exerted more force.
B	$a = v/t$ $a = - (.2 - .6) / .1$ $a = .4/.1$ $a = -4 \text{ m/s}^2$
C	$F = ma$ $F = 1 \times (-4)$ $F = -2 \text{ N}$

Score Point 0

Part	Student Response
A	Since Cart Y is .5 kilograms bigger than Cart X the force exerted was greater on cart X from Y than from X on Y.
B	$A = V/T$ $V = 6 \text{ meters per second}$ $T = .5 \text{ seconds}$ $A = 6/0.5$ $A = 12$ $\text{meters per second squared}$
C	The Magnitude exerted on cart Y by X is .5 newtons

Item 20 Sample Student Work and Scoring Guide

Scoring Guide

Score	Description
4	The response demonstrates a thorough understanding of electromagnetic and mechanical waves and their properties. The response correctly calculates the speed of a sound wave. The response clearly describes two differences between light waves and sound waves. The response also clearly describes one difference between radio waves and visible light waves.
3	The response demonstrates a general understanding of electromagnetic and mechanical waves and their properties.
2	The response demonstrates a limited understanding of electromagnetic and mechanical waves and their properties.
1	The response demonstrates a minimal understanding of electromagnetic and mechanical waves and their properties.
0	The response is incorrect or contains some correct work that is irrelevant to the skill or concept being measured.

Score Point 4

Part	Student Response
A	The speed of the sound wave is 344.83 m/s. $\text{speed} = d/\Delta t = 200 \text{ m} / 0.58 \text{ s} \sim 344.83 \text{ m/s}$
B	Visible light waves are electromagnetic waves, so they do not need a medium to travel through. Sound waves are mechanical waves, so they need a medium to travel through. Also, visible light waves are transverse waves, meaning the movement of the particles in the wave is perpendicular to the direction of the wave movement. Sound waves are longitudinal waves, so the molecule movement is parallel to the direction of the wave movement.
C	A second difference between radio waves and visible light waves is that radio waves have a lower frequency than visible light waves. According to the electromagnetic spectrum, radio waves have the lowest frequency. Visible light waves are in the middle of the spectrum and have a higher frequency than radio waves.

Score Point 3

Part	Student Response
A	$S = d/\Delta t$ $S = 200/0.58$ $S \sim 344.83 \text{ m/s}$
B	Visible light waves can travel through a vacuum while sound waves cannot. And light waves can be seen while sound waves can be heard.
C	Radio waves have a longer wavelength than visible light waves.

Score Point 2

Part	Student Response
A	speed = 344.83 m/s $v = d/\Delta t$ $d = 200 \text{ m}$ $\Delta t = 0.58\text{s}$ $v = 200/0.58$ $v = 344.83 \text{ m/s}$
B	Two differences between the light waves and sound waves are longitudinal while light waves are transverse and sound waves are electromagnetic waves while light waves are mechanical waves.
C	Another difference between visible light waves and radio waves is visible light waves travel much faster than radio waves.

Score Point 1

Part	Student Response
A	344 m/s
B	1. You can't see sound waves in person 2. You can't hear light waves in person
C	Radio waves can travel from one place to another through something, while light waves can't.

Score Point 0

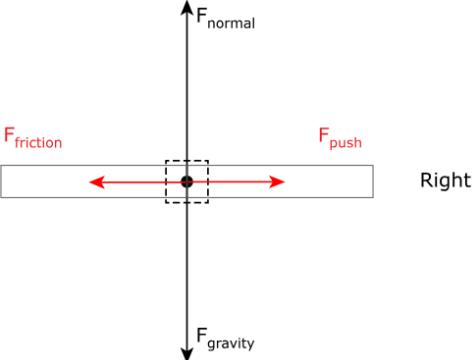
Part	Student Response
A	$116.0c$ $200\text{m} \times 0.58\text{s} = 116.0c$
B	The visible light waves was gone when it hit the Ball. The sound became more loud then when you don't hit it.
C	another way that visible light is always there and radio waves not a lot of people hear it.

Item 21 Sample Student Work and Scoring Guide

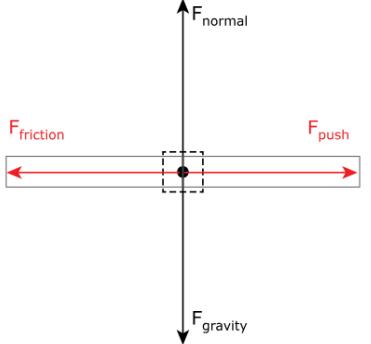
Scoring Guide

Score	Description
4	The response demonstrates a thorough understanding of using free-body force diagrams. The response correctly shows the horizontal forces acting on a bookcase by adding arrows and force labels to a free-body force diagram. The response correctly identifies a way to change a floor that would increase the amount of force required to move the bookshelf and clearly explains the reasoning. The response also correctly identifies a different way to change the bookcase that would increase the amount of force required to move the bookshelf and clearly explains the reasoning.
3	The response demonstrates a general understanding of using free-body force diagrams.
2	The response demonstrates a limited understanding of using free-body force diagrams.
1	The response demonstrates a minimal understanding of using free-body force diagrams.
0	The response is incorrect or contains some correct work that is irrelevant to the skill or concept being measured.

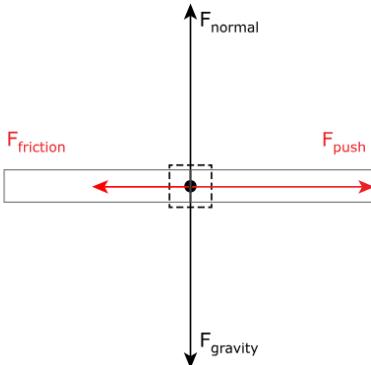
Score Point 4

Part	Student Response
A	
B	<p>A change to the floor that would affect the amount of force required to move the bookcase at a constant speed would be if the floor was rougher, like if sandpaper was added to it. A rough floor would increase the amount of friction acting on the bookcase so it would take a bigger force to push the bookcase.</p>
C	<p>A different change to the bookcase that would affect the amount of force required to move the bookcase at a constant speed would be if the bookcase had more mass added to it, like if books were put on it. More mass would take a bigger force to push the bookcase.</p>

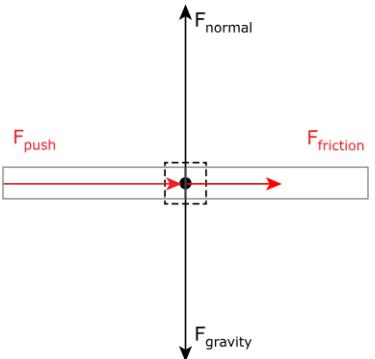
Score Point 3

Part	Student Response
A	
B	<p>One change would be to raise part of the floor so that it was on an angle. You'd have to push the bookcase harder if you were pushing it up an angled floor.</p>
C	<p>A different change would be to add more books to the bookcase or to remove books from the bookcase. This would change the mass of the bookcase.</p>

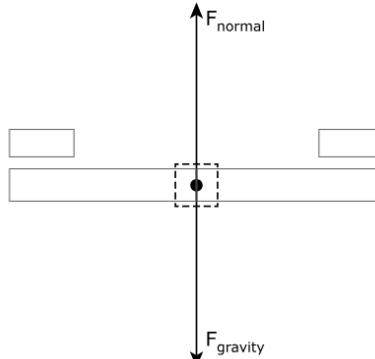
Score Point 2

Part	Student Response
A	
B	<p>You could polish the floor so it would be smoother. If you did that then it would not take as much force to push it.</p>
C	<p>You could remove the friction force.</p>

Score Point 1

Part	Student Response
A	<p>Left Right</p> 
B	You could make the amounts of push force uneven.
C	You could change the mass of the bookcase.

Score Point 0

Part	Student Response
A	<p>Left Right</p> 
B	Add more gravity. The bookcase would be pulled toward the floor if there was more gravity.
C	Add more normal force. The bookcase would be pushed off the floor if there was more normal force.

Item 38 Sample Student Work and Scoring Guide

Scoring Guide

Score	Description
3	The response demonstrates a thorough understanding of how the transfer of thermal energy between objects of different temperatures results in thermal equilibrium. The response correctly compares the average molecular motion of the water molecules in containers 1 and 2. The response clearly describes how temperature data can be used to show that energy is conserved. The response also correctly compares the average molecular motion of water molecules in containers 1 and 2 when they are in thermal equilibrium and clearly explains the reasoning.
2	The response demonstrates a partial understanding of how the transfer of thermal energy between objects of different temperatures results in thermal equilibrium.
1	The response demonstrates a minimal understanding of how the transfer of thermal energy between objects of different temperatures results in thermal equilibrium.
0	The response is incorrect or contains some correct work that is irrelevant to the skill or concept being measured.

Score Point 3

Part	Student Response
A	During the first 100 s in investigation 1, the average molecular motion of the water molecules in container 1 decreased <input style="width: 100px; height: 20px; border: 1px solid black; margin: 2px 0;" type="text"/> , and the average molecular motion of the water molecules in container 2 increased. <input style="width: 100px; height: 20px; border: 1px solid black; margin: 2px 0;" type="text"/>
B	The Law of Conservation of Energy is shown in the table from investigation 1. As the temperature in container one decreased, the temperature in container two increased by an equal amount. Since the substances in both containers had the same specific heat and mass and change in temperature, this shows that they also had equal transfers of heat. The heat from container one transferred to container two.
C	The average molecular movement in containers one and two are equal. This is shown because they have equal temperatures and temperature is the measure of the average kinetic energy in a substance. Kinetic energy is the energy of motion, so if there is equal amounts of kinetic energy, there is an equal amount of molecular motion.

Score Point 2

Part	Student Response
A	During the first 100 s in investigation 1, the average molecular motion of the water molecules in container 1 decreased <input type="button" value="▼"/> , and the average molecular motion of the water molecules in container 2 increased. <input type="button" value="▼"/>
B	The student could say that for the final two seconds the temperature stayed the same so that is how the energy was conserved.
C	The average molecular motion of molecules would be the same in both container 1 and container 2 because they are both equal in temperature.

Score Point 1

Part	Student Response
A	During the first 100 s in investigation 1, the average molecular motion of the water molecules in container 1 decreased <input type="button" value="▼"/> , and the average molecular motion of the water molecules in container 2 increased. <input type="button" value="▼"/>
B	The student could use data from investigation 1 because the heat is being transferred by both container 1 and container 2, making both the containers transfer thermal energy.
C	In container 1 the temperature started to drop from 95.0 and eventually got down to 50.0. The temperature in container 2 began to increase from 5.0 and eventually got to 50.0. Because the heat was stronger in container 1 that heat got transferred into container 2 and made the heat go up, and container 2's temperature go down because all the heat from container 1 was being extracted by container 2. Thermal equilibrium was being reached because heat was coming out of container 1 and being transferred into container 2 so both containers got to the same temperature which ended up being 50.0.

Score Point 0

Part	Student Response
A	During the first 100 s in investigation 1, the average molecular motion of the water molecules in container 1 decreased <input type="button" value="▼"/> , and the average molecular motion of the water molecules in container 2 remained the same. <input type="button" value="▼"/>
B	Well data one shows how the temperature started off as 95.0 and I feel like it is being divided by the top of the temperature.
C	My reasoning for this is container two is not the same because it goes lower than the first one

Item 43 Sample Student Work and Scoring Guide

Scoring Guide

Score	Description
4	The response demonstrates a thorough understanding of motion and momentum during a collision. The response correctly calculates both the change in momentum of the soccer ball and the average net force applied to the soccer ball. The response correctly identifies one way to reduce the average net force applied to the soccer ball and clearly explains the reasoning. The response also correctly identifies factors that will change during the investigation, those that must be kept constant, and those that do not affect the outcome.
3	The response demonstrates a general understanding of motion and momentum during a collision.
2	The response demonstrates a limited understanding of motion and momentum during a collision.
1	The response demonstrates a minimal understanding of motion and momentum during a collision.
0	The response is incorrect or contains some correct work that is irrelevant to the skill or concept being measured.

Score Point 4

Part	Student Response		
A	<p>before $p = 0.42\text{kg} * 22\text{m/s}$ $p = 9.24 \text{ kg} \times \text{m/s}$ after $p = 0.\text{kg} \times \text{m/s}$ the momentum of the ball decreased by $9.24 \times \text{m/s}$</p>		
B	$F * \Delta t = \Delta p$ $F * 0.25\text{s} = 9.24 \text{ kg} \times \text{m/s}$ $F = 4 \times 9.24 \text{ kg} \times \text{m/s}^2$ $F = 36.96 \text{ N}$		
C	<p>You can decrease the net force by decreasing the speed at which the ball is kicked, since this will decrease the momentum, and a decrease in momentum results in a decrease in force.</p>		
D	Factors That Will Change <div style="border: 1px solid blue; padding: 5px; display: inline-block;"> how hard the ball is kicked the ball's velocity after being kicked </div>	Factors That Must Remain Constant (Controlled) <div style="border: 1px solid blue; padding: 5px; display: inline-block;"> the ball's mass how inflated the ball is </div>	Factors That Do Not Affect The Outcome <div style="border: 1px solid blue; padding: 5px; display: inline-block;"> the amount of light on the field the time of day the data are collected </div>

Score Point 3

Part	Student Response									
A	$p = mv$ $p = 0.42 \times 22$ $p = 9.24 \text{ kg} \times \text{m/s}$									
B	$f = ma$ $m = 0.42$ $a = ?$ To find the the average net force, you need to find the acceleration. $a = v/t$ $a = 22/0.25$ $a = 88 \text{ (m/s)}^2$ $F = 0.42 \times 88$ $f = 36.96 \text{ N}$									
C	If you make the strings tighter, the ball will fall into the net causing the time it took to fall to the ground quicker. This means that everything will be reduced because it is a smaller time than the orgininal.									
D	<table> <thead> <tr> <th>Factors That Will Change</th> <th>Factors That Must Remain Constant (Controlled)</th> <th>Factors That Do Not Affect The Outcome</th> </tr> </thead> <tbody> <tr> <td>how hard the ball is kicked</td> <td>the ball's mass</td> <td>the time of day the data are collected</td> </tr> <tr> <td>the ball's velocity after being kicked</td> <td>how inflated the ball is</td> <td>the amount of light on the field</td> </tr> </tbody> </table>	Factors That Will Change	Factors That Must Remain Constant (Controlled)	Factors That Do Not Affect The Outcome	how hard the ball is kicked	the ball's mass	the time of day the data are collected	the ball's velocity after being kicked	how inflated the ball is	the amount of light on the field
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how hard the ball is kicked	the ball's mass	the time of day the data are collected								
the ball's velocity after being kicked	how inflated the ball is	the amount of light on the field								

Score Point 2

Part	Student Response									
A	$0.42 \times 22 = 9.24 \text{ N}$									
B	$0.42 \times 22 (0.25) = 2.31$									
C	One way to reduce the average net force on the ball is to kick from a closer distance to the goal, so the force being put onto the ball doesn't have to be as high.									
D	<table> <thead> <tr> <th>Factors That Will Change</th> <th>Factors That Must Remain Constant (Controlled)</th> <th>Factors That Do Not Affect The Outcome</th> </tr> </thead> <tbody> <tr> <td>how hard the ball is kicked</td> <td>the ball's mass</td> <td>the time of day the data are collected</td> </tr> <tr> <td>the ball's velocity after being kicked</td> <td>how inflated the ball is</td> <td>the amount of light on the field</td> </tr> </tbody> </table>	Factors That Will Change	Factors That Must Remain Constant (Controlled)	Factors That Do Not Affect The Outcome	how hard the ball is kicked	the ball's mass	the time of day the data are collected	the ball's velocity after being kicked	how inflated the ball is	the amount of light on the field
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how hard the ball is kicked	the ball's mass	the time of day the data are collected								
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Score Point 1

Part	Student Response		
A	0.4 kg x 22m / s = 9.24		
B	0.4 kg x 22m / s = 9.24		
C	To reduce the net force you increase the speed of the soccer ball and see where it stopped in the net.		
D	Factors That Will Change <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">the amount of light on the field</div> <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">how inflated the ball is</div>	Factors That Must Remain Constant (Controlled) <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">how hard the ball is kicked</div> <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">the ball's mass</div>	Factors That Do Not Affect The Outcome <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">the time of day the data are collected</div> <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">the ball's velocity after being kicked</div>

Score Point 0

Part	Student Response		
A	$0.42 \div 22 = 52.3\text{m}$		
B	$0.25 \times 0.42 = 0.105$		
C	Stop it with your hands		
D	Factors That Will Change <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">the time of day the data are collected</div> <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">the amount of light on the field</div>	Factors That Must Remain Constant (Controlled) <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">how inflated the ball is</div> <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">the ball's mass</div>	Factors That Do Not Affect The Outcome <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">how hard the ball is kicked</div> <div style="border: 1px solid #ccc; padding: 5px; display: inline-block;">the ball's velocity after being kicked</div>