MCAS High School Introductory Physics
Paper-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	C
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	A, B
7	Waves	HS-PS4-5	C. Evidence, Reasoning, and Modeling	SR	2	Part A: A Part B: B; B
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	A; C
10	Energy	HS-PS3-1	C. Evidence, Reasoning, and Modeling	SR	2	Part A: D Part B: C
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	B
17	Motion, Forces, and Interactions	HS-PS2-1	B. Mathematics and Data	CR	3	see pages 3–4
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 5–6
21	Motion, Forces, and Interactions	HS-PS2-10(MA)	C. Evidence, Reasoning, and Modeling	CR	4	see pages 7–9

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

**Pages 3–14 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	D
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: B; C 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	C
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 10–11
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	B; A; B
41	Energy	HS-PS3-1	B. Mathematics and Data	SR	1	A
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 12–14

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

**Pages 3–14 provide sample student responses to constructed-response items.

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 3rd law: for every action there is an equal and opposite reaction.
B	$a = \Delta v/\Delta t$ $a = -.4 / .1$ $a = -4\ m/s^2$
C	$f = ma$ $f = .5 \times (-4)$ $f = -2$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 3rd law which states that for every action there is an equal and opposite reaction.
B	$v_f = v_i + a\Delta t$ $(v_f - v_i) \div t = a$ $(0.2 - 0.6) \div 0.1 = a$ $a = -4\ m/s^2$
C	$f = ma$ $f = 0.5 \times (-4)$ $f = -8\ N$

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 m/s^2
C	F = ma F = 1 × (-4) F = -2 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 meters per second T = .5 seconds A = 6/0.5 A = 12 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. speed = $d/\Delta t$ = 200 m / 0.58 s ~344.83 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~344.83 m/s
B	Visible light waves can travel through a vacuume while sound waves cannot. And light waves can be seen while sound wave can be heard.
C	Radio waves has a longer wavelength than visible light waves.

Score Point 2

Part	Student Response
A	speed = 344.83 m/s v = d/Δt d = 200 m Δt = 0.58s v = 200/0.58 v = 344.83 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

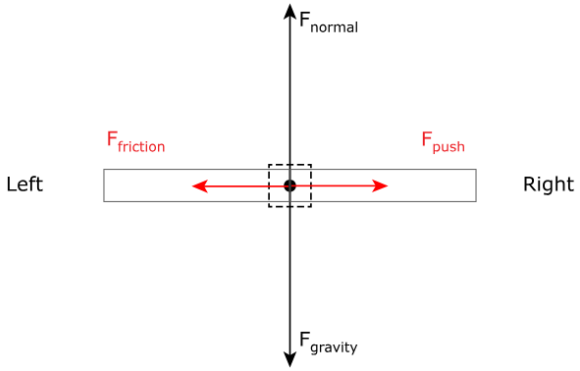
Part	Student Response
A	116.0c 200m x 0.58s = 116.0c
B	The visible light waves was gone when it hit the Ball. The sound became more loud then when you don't hit it.
C	another way that visible light is always there and radio waves not a lot of people hear it.

Item 21 Sample Student Work and Scoring Guide

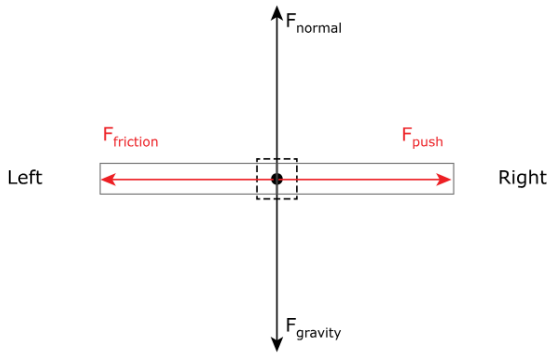
Scoring Guide

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.

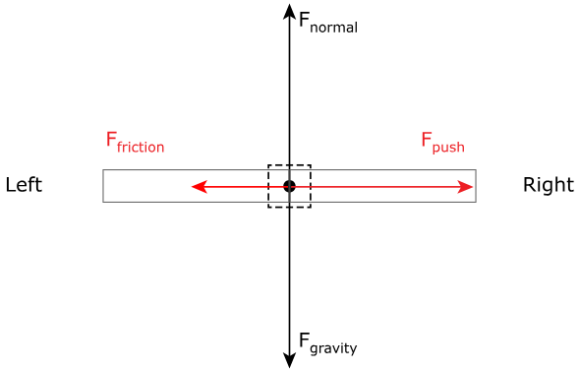
Score Point 4

Part	Student Response
A	
B	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.
C	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.

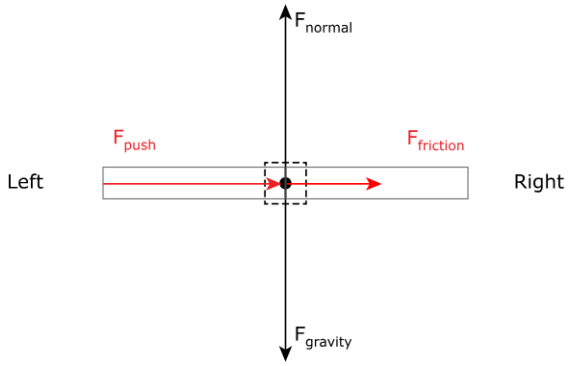
Score Point 3

Part	Student Response
A	
B	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.
C	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.

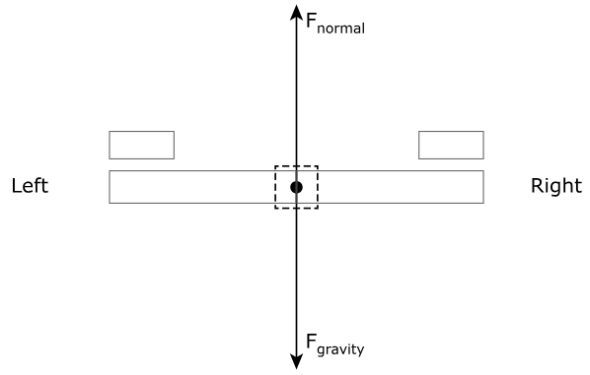
Score Point 2

Part	Student Response
A	
B	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.
C	You could remove the friction force.

Score Point 1

Part	Student Response
A	
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	
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 , and the average molecular motion of the water molecules in container 2 increased.
B	The Law of Conservation of Energy is shown in the table from investigation 1. As the temperature in conatainer 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 an 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 , and the average molecular motion of the water molecules in container 2 increased.
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 , and the average molecular motion of the water molecules in container 2 increased.
B	The student could use data from investigation 1 because the heat is being transfered by both containeer 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 transfered into container 2 and made the heat go up, and containers two's temperature go down because all the heat from container 1 qas being extracted by container 2. Thermal equilibrium was being reached because heat was coming out of container 1 and being transfered into container 2 so both containers got to the same temperature which ended up being 50.0.

Score Point 0

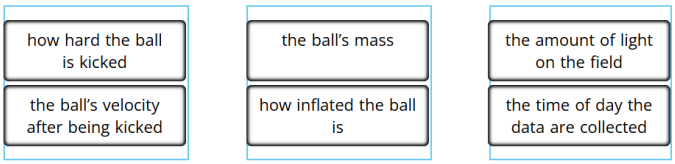
Part	Student Response
A	During the first 100 s in investigation 1, the average molecular motion of the water molecules in container 1 decreased , and the average molecular motion of the water molecules in container 2 remained the same.
B	Well data one shows how the tempertuture statred off as 95.0 anc I feel like it is being divided by the top of the tempertuture.
C	My reasoning for this is contanier 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	before p = 0.42kg * 22m/s p = 9.24 kg × m/s after p = 0.kg × m/s the momentum of the ball decreased by 9.24 × m/s
B	F * Δt = Δp F * 0.25s = 9.24 kg × m/s F = 4 × 9.24 kg×m/s^2 F = 36.96 N
C	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.
D	

Score Point 3

Part	Student Response
A	p = mv p = 0.42 × 22 p = 9.24 kg × 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 $(m/s)^2$ F = 0.42 × 88 f = 36.96 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	**Factors That Will Change** how hard the ball is kicked the ball's velocity after being kicked **Factors That Must Remain Constant (Controlled)** the ball's mass how inflated the ball is **Factors That Do Not Affect The Outcome** the time of day the data are collected the amount of light on the field

Score Point 2

Part	Student Response
A	0.42 x 22 = 9.24 N
B	0.42 x 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	**Factors That Will Change** how hard the ball is kicked the ball's velocity after being kicked **Factors That Must Remain Constant (Controlled)** the ball's mass how inflated the ball is **Factors That Do Not Affect The Outcome** the time of day the data are collected the amount of light on the field

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** the amount of light on the field how inflated the ball is **Factors That Must Remain Constant (Controlled)** how hard the ball is kicked the ball's mass **Factors That Do Not Affect The Outcome** the time of day the data are collected the ball's velocity after being kicked

Score Point 0

Part	Student Response
A	0.42 ÷ 22 = 52.3m
B	0.25 ×0.42 = 0.105
C	Stop it with your hands
D	**Factors That Will Change** the time of day the data are collected the amount of light on the field **Factors That Must Remain Constant (Controlled)** how inflated the ball is the ball's mass **Factors That Do Not Affect The Outcome** how hard the ball is kicked the ball's velocity after being kicked