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AP PHYSICS 1

AP物理1 新样题

「2021 版本」

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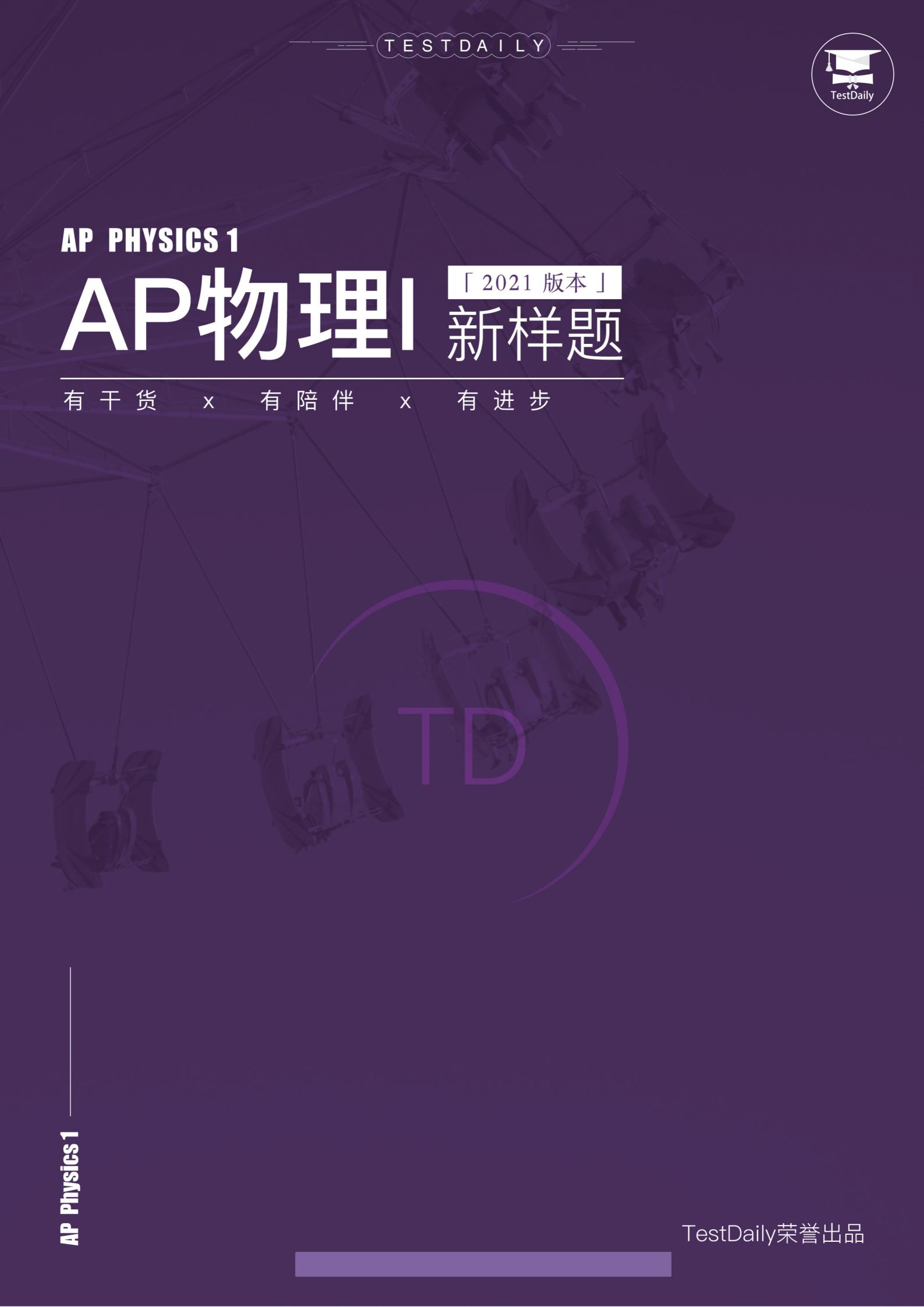

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AP Physics 1

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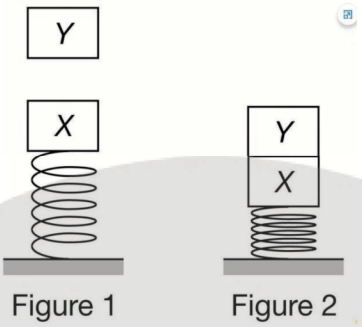

Figure 1 Figure 2

1. Block Y with mass m_Y falls onto and sticks to block X, which is attached to a vertical spring, as shown in Figure 1. A short time later, as shown in Figure 2, the blocks are momentarily at rest. At that moment, block Y exerts a force of magnitude F_{down} on block X, and block X exerts a force of magnitude F_{up} on block Y.

Which of the following correctly relates F_{up}, F_{down} , and m_Y g at the instant shown in Figure 2?

A. $\left(F_{\text{up}} = F_{\text{down}}\right) > m_Y g$

B. $\left(F_{\text{up}} = m_Y g\right) > F_{\text{down}}$

C. $m_Y g > F_{\text{up}} > F_{\text{down}}$

D. $F_{\text{up}} = F_{\text{down}} = m_Y g$

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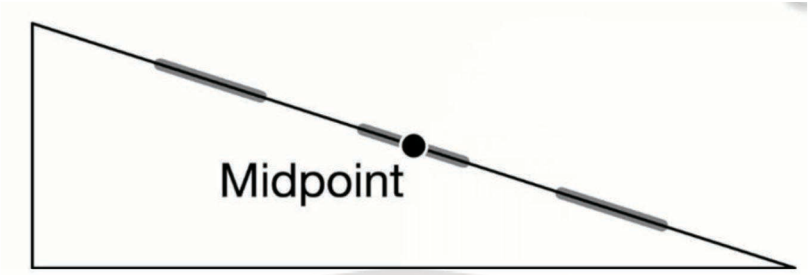

2. A block is released from rest and slides down a ramp. The surface of the ramp has three rough sections where the friction between the surface and the block is not negligible, as shown by the shaded regions.

Measuring which of the following will allow for the best estimate of the block's instantaneous acceleration when the block is at the midpoint of the ramp?

A. The total distance traveled by the block and the total elapsed time

B. The final speed of the block and the total elapsed time

C. The distance between the points just before and just after the midpoint and the time it takes the block to travel between them

D. The speed of the block at points just before and just after the midpoint and the time it takes the block to travel between them

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Questions 3 through 5 refer to the following material.

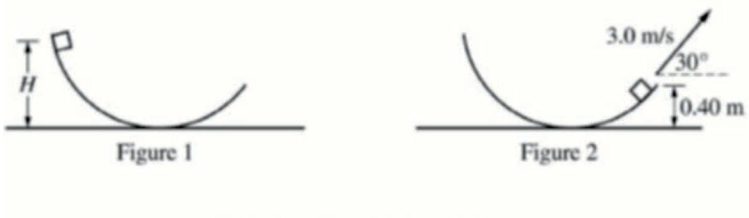

Figure 1 Figure 2

Note: Figures not drawn to scale.

The figures show a small block of mass 0. 20 kg on a track in the shape of a circular arc. The block is released from rest at a height H above the floor, as shown in Figure 1. The block slides along the track with negligible friction and leaves it at a height of 0. 40 m above the floor and a speed of 3. 0 m/s at a 30° angle as shown in Figure 2.

3. The height H is most nearly

A. 0. 45m

B. 0. 51m

C. 0. 86m

D. 1. 7m

4. The magnitude of the gravitation force exerted on the block is F_g, and the magnitude of the normal force exerted by the track on the block is F_n. Which of the following correctly compares the magnitudes of these two forces when the block is at the lowest point on the track?

A. $F_n > F_g$

B. $F_n = F_g$

C. $F_n < F_g$

D. The magnitudes cannot be compared without knowing the radius of the arc of the track.

5. After the block leaves the track, what is the block's speed when it reaches the highest point of its motion?

A. 0

B. 1. 5m/s

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C. 2. 6m/s

D. 3. 0m/s

6. Two people sit facing each other on a train that is traveling at speed v. Which of the following is true of the speed of the center of mass of the two-person system while riding on the train? Select two answers.

A. It is zero relative to person 1.

B. It is zero relative to the ground.

C. It is equal to v relative to person 1.

D. It is equal to v relative to the ground.

7. An astronomer wishes to determine the mass of Jupiter. Which of the following pairs of measurements would allow the mass of Jupiter to be determined? Assume the orbits of Jupiter's moons to be circular. Select **two** answers.

A. The speed of one of Jupiter's moons and the radius of the moon's orbit.

B. The speed of one of Jupiter's moons and the period of orbit of the moon around Jupiter.

C. The mass of the moon and the radius of the moon's orbit.

D. The mass of the moon and the period of orbit of the moon around Jupiter.

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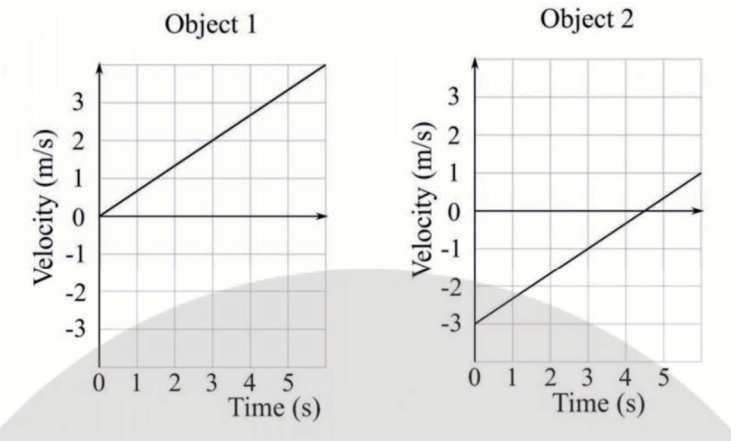

8. Two objects move along a straight, horizontal track. The graphs show the velocity of each object as a function of time during the same time interval. Which of the following quantities are the same for both objects during the interval? Select two answers.

A. Average velocity

B. Average acceleration

C. Change in position

D. Change in velocity

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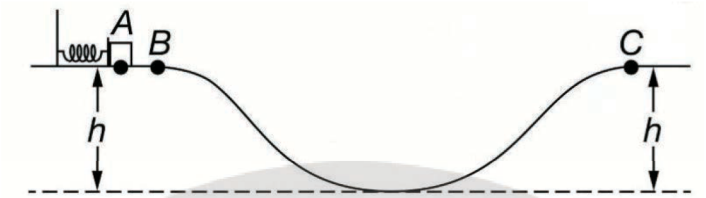
Section II: Multiple-Choice Question



1. A block is held at rest against a compressed spring at point at the top of a frictionless track of height as shown. The block is released, loses contact with the spring at point , and slides along the track until it passes point , also at height .

How do the potential energy ***U*** of the block-Earth system and the kinetic energy ***K*** of the block at point ***C*** compare with those at point ***A***?

A.

Potential Energy of Block-Earth System	Kinetic Energy of Block
$U_C = U_A$	$K_C = K_A$

B.

Potential Energy of Block-Earth System	Kinetic Energy of Block
$U_C = U_A$	$K_C > K_A$

C.

Potential Energy of Block-Earth System	Kinetic Energy of Block
$U_C > U_A$	$K_C = K_A$

D.

Potential Energy of Block-Earth System	Kinetic Energy of Block
$U_C > U_A$	$K_C > K_A$

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2. A person exerts an upward force on a box, as shown. The box may be moving upward, downward, or not at all while the person exerts the upward force. For which of the following motions of the box is the work done by the person on the box correctly indicated?

A.

Motion of Box	Work Done by Person on Box
No motion	Positive

B.

Motion of Box	Work Done by Person on Box
Upward with decreasing speed	Negative

C.

Motion of Box	Work Done by Person on Box
Downward with constant speed	Zero

D.

Motion of Box	Work Done by Person on Box
Downward with increasing speed	Negative

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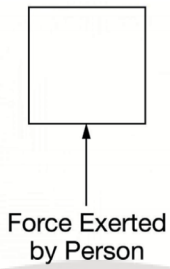

3. Two satellites are in circular orbits around Earth. Satellite 1 has mass mo and orbital radius of 2RE, where RE is the radius of Earth. Satellite 2 has mass 2mo and an orbital radius of 3RE. Which of the following correctly compares the magnitude F of the force exerted by Earth on each satellite and the speed U of each satellite?

A.

Speed	Force
$F_1 > F_2$	$v_1 > v_2$

B.

Speed	Force
$F_1 > F_2$	$v_2 > v_1$

C .

Speed	Force
$F_2 > F_1$	$v_1 > v_2$

D .

Speed	Force
$F_2 > F_1$	$v_2 > v_1$

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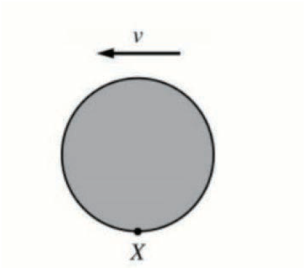

Top View

4. A stone disk is sliding on frictionless ice to the west with speed v, as shown in the figure. As the disk slides by, a child uses a rubber mallet to hit the disk at point *X*, exerting a force directly toward the center of the disk. The child hits point *X* every half second for about 10 s, changing the trajectory of the disk but not causing it to rotate.

Which of the following most closely approximates the path of the disk while the child is hitting it?

A. 

A northward linear path

B. 

A northwestward linear path

C. 

A parabolic path

D. 

A circular path

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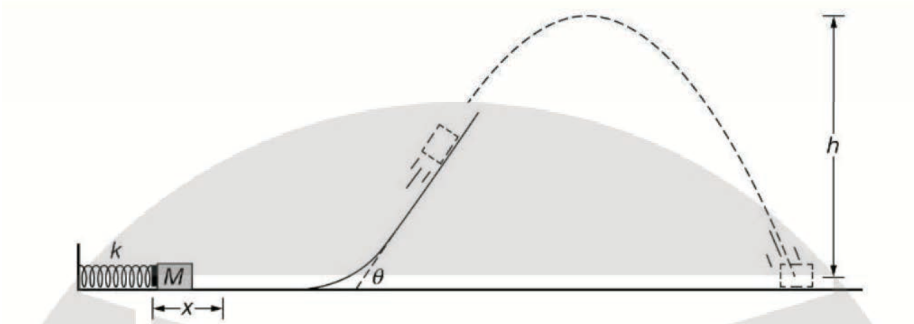
Section III: Free-Response Question



1. A box is pressed against a horizontal spring, compressing the spring from its relaxed length. The box is then released, and the spring launches the box horizontally along a track that ends in a ramp, as shown. The box has enough speed to leave the ramp, and the box reaches a maximum vertical height above the floor. Assume there is negligible friction between the box and the track and air resistance is negligible.

k is the spring constant of the spring.

x is the distance the spring is compressed.

M is the mass of the box.

θ (theta)is the angle of the ramp from the horizontal.

h is the maximum height reached by the box.

The scenario is repeated using a stiffer spring with a spring constant that has a greater value for ***k*** than that of the original spring. The stiffer spring is compressed the same distance ***x***, and the same box is used.

a. Indicate how using a stiffer spring would affect the maximum height reached by the box, and explain why without mathematically deriving a relation for *h*.

b. Students derive an equation for the maximum height, $h = \frac{(\sin^2\theta)kx^2}{2Mg}$, which may or may not be correct. Is this equation consistent with your claim in **part a**? Explain why or why not.

Two students are discussing the motion of the box when it is at its maximum height and make the following statements:

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Student 1: The speed of the box at its maximum height is zero because the kinetic energy is a minimum at the top of the trajectory.
Student 2: Only the vertical component of the velocity is zero at the maximum height, because the vertical component of the acceleration is zero at the top of the trajectory.

c. Which underlined phrase or phrases in student 1's statement are correct, if either? If neither phrase is correct, write “none. ”

d. Which underlined phrase or phrases in student 1's statement are incorrect, if either? If neither phrase is incorrect, write “none. ”

e. Which underlined phrase or phrases in student 2's statement are correct, if either? If neither phrase is correct, write "none.”

f. Which underlined phrase or phrases in student 2's statement are incorrect, if either? If neither phrase is incorrect, write“none. ”

g. Consider the system consisting of the box and the spring, but not Earth. How does the energy of the system when the spring is fully compressed compare to the energy of the system at the moment immediately before the box hits the ground? Justify your answer.

h. If the friction between the track and the box were not negligible, state one way in which the setup could be changed such that the maximum height of the box was the same as in the original setup.

The graph shows the horizontal component of the displacement of the box as a function of time. The graph represents the entire time the box is in the air after the box is launched from the ramp at an angle θ to the horizontal.

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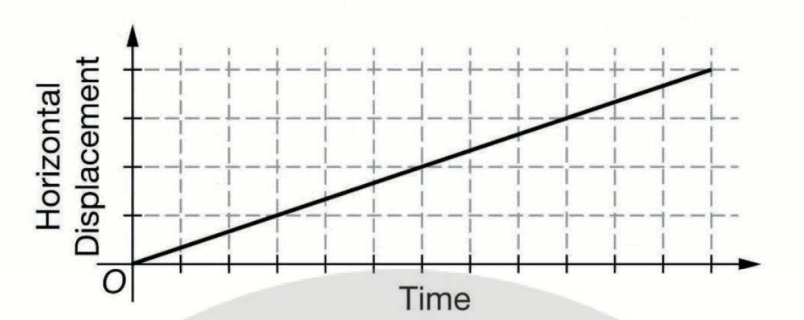

i. How would the slope of the graph be different, if at all, if the ramp angle were larger than θ , but less than 90 degrees, and the height of the end of the ramp were the same? Justify your response.

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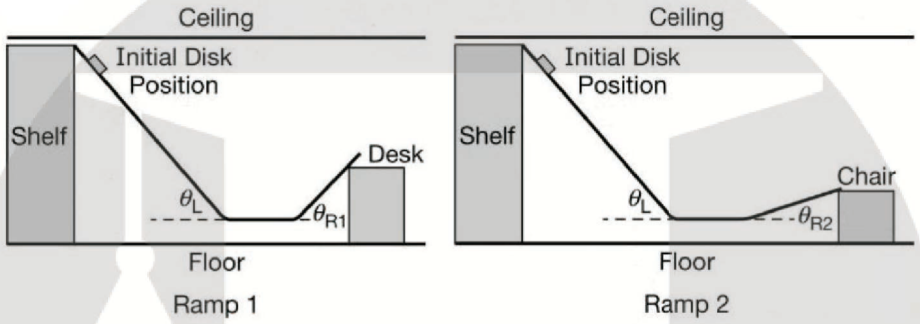
2. A class of physics students is investigating projectile motion using a variety of equipment. Assume air resistance can be ignored in all cases.

One group constructs a long ramp as shown in Ramp 1. In their experiment, they release a disk from the left side of the ramp and allow the disk to launch off the right side. The ramp is smooth enough that friction can be ignored. The left side of the ramp is supported by the top of a shelf, and the other side is supported by the top of a desk. The left and right sides of the ramp are at angles θ_L and θ_{R1} with the horizontal respectively.



Note: Figures not drawn to scale.

The students release a disk and measure the maximum height it reaches after leaving the right side of the ramp. The students then adjust the ramp so that $\theta_{R2} < \theta_{R1}$ and the height of the right side of the ramp is lower as shown in the Ramp 2 configuration. Assume the length of the right section of the ramp is the same in both cases.

a. Will the disk launched from Ramp 2 reach a maximum height that is greater than, less than, or equal to the maximum height reached by the disk launched from Ramp 1? Justify your answer.

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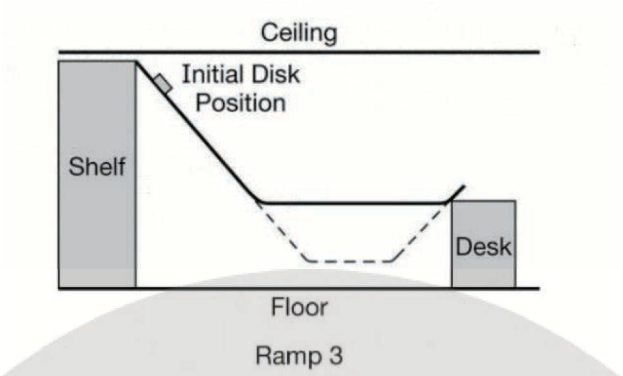
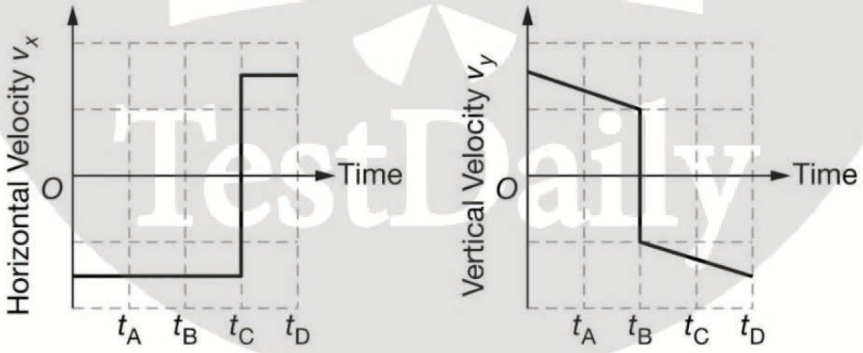


Ramp 3

Note: Figure not drawn to scale.

The students then adjust the ramp into the configuration labeled Ramp 3 in which the horizontal section of the ramp is at a greater height than in Ramp 1, which is represented by the dotted line. The students release the disk on Ramp 3.

b. On which ramp, Ramp 1 or Ramp 3, if either, does the disk spend more time on the horizontal section of the ramp before launching off the right side? Explain your answer.



One group uses a device that can launch a steel ball. The group launches the ball and it bounces off the ceiling, floor, and wall several times though not necessarily in that order. Each collision can be modeled as elastic, and friction between the ball and the surfaces is negligible. The graphs show the horizontal and vertical components of the velocity of the ball during some time interval in the ball's motion. The positive direction is taken to be upward.

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c. During the time interval shown in the graphs, the ball has two collisions. In a clear, coherent, paragraph-length response, identify the times when these collisions occur using the times indicated on the graph, and explain how you know whether each collision is with the wall, the ceiling, or the floor.

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2021 Digital Exam Practice

AP Physics 1: Algebra-Based

Scoring Materials for Digital Exam Practice

Please note: the digital exam practice resource was developed for students to complete technology checks, experience the digital platform, and practice answering exam questions, including each type of multiple-choice and free-response question they will encounter on exam day.

This digital exam practice is not a full-length exam, and it does not represent the complete scope of content and skills that students will see on the actual AP exam. This digital exam practice includes only content that would typically be taught in the first half of the school year, following the unit sequence in the AP Physics 1: Algebra-Based Course and Exam Description. For more information on the 2021 Exam format, please visit: apcentral.collegeboard.org/pdf/ap-2021-exam-formats.pdf

AP Exams are scored differently than traditional high school or college exams. When an AP Exam is administered, psychometric analysis determines the score ranges corresponding with each AP Exam score (5, 4, 3, 2, and 1) based on a composite score scale that combines and weights the different exam parts. Earning 40-50% of the available points can result in a score of 3 or better on many AP Exams. However, because the number of points corresponding with each AP Exam score can vary on different exams, students and teachers should not use the results of the digital exam practice to predict performance on the 2021 AP Exam.

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Multiple-Choice Answer Key

Multiple-Choice Question	Answer
1	A
2	D
3	B
4	C
5	A
6	C
7	D
8	A
9	C
10	A, D
11	A, B
12	B, D

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Question 1: Qualitative/Quantitative Translation (QQT) — 15 points

a.

For a statement that with a stiffer spring the spring constant would increase (or the average force would increase), so the speed of the box as it leaves the spring will be larger — **1 point**

For a statement that because the speed of the box as it leaves the spring will be greater, and everything else remains the same, the maximum height of the block will increase — **1 point**

Example response for part a.

A stiffer spring means that the spring constant is larger, which means that there is more initial energy stored in the spring (or that the average net force on the box is greater), which means that the launch speed is greater, so with everything else the same the box will reach a larger maximum height.

Total for part a. 2 points

b.

For indicating "yes", with an attempt at a justification using functional dependence — **1 point**

For indicating that, since k is in the numerator if k increases, h will increase — **1 point**

Example response for part b.

Yes, it is consistent with my reasoning – since k is in the numerator, if k increases, h will also increase.

Total for part b. 2 points

c.

For a correct statement and no incorrect statements — **1 point**

Example responses for part c.

Student 1 is correct in saying that the kinetic energy is a minimum at the top of the trajectory.

OR

The second statement

d.

For an incorrect statement and no correct statements — **1 point**

Example responses for part d.

Student 1 is incorrect in saying that the speed of the block is zero at the max height

OR

The first statement

e.

For a correct statement and no incorrect statements — **1 point**

Example response for part e.

Student 2 is correct in saying that only the vertical component of the speed is zero at the max height

OR

The first statement

f.

For an incorrect statement and no correct statements — **1 point**

Example response for part f.

Student 2 is incorrect in saying that the vertical component of the acceleration is zero at the top of the trajectory.

OR

The second statement

g.

For indicating that the energy of the box/spring system remains the same — **1 point**

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	For indicating that there is mechanical energy in the spring	**1 point**
	OR	
	For indicating that the box returns to the same height	
	For indicating that just before the box lands all that energy is again kinetic energy, and none is lost	**1 point**
	OR	
	For indicating that the net work done by gravity is zero	
	Example responses for part (g) *The energy of the spring-box system initially is spring potential energy, and just before the box lands, all the energy is kinetic energy, and because there is no net work done by outside forces, the energy of the spring-box system is the same.* **OR** *The energy of the spring-box system remains the same because the box returns to the same height, and so the net work done by gravity is zero.*	
		Total for part g. 3 points
h.	For indicating a valid change that could be made so that the maximum height would be the same	**1 point**
	Example response for part (h) *Nonnegligible friction would cause mechanical energy to be dissipated. Therefore, the compression distance could be increased so that the spring transfers more energy to the box, offsetting the loss in energy from friction.*	
i.	For indicating that the slope of the line would be smaller	**1 point**
	For indicating that with a larger angle, the horizontal component of the initial velocity is smaller	**1 point**
	For indicating that the slope of the horizontal position as a function of time graph is equal to the horizontal velocity of the box	**1 point**
	Example response for part i. *Since the graph is of horizontal position as a function of time, the slope of the line represents the horizontal velocity as a function of time. If the box were launched at a larger angle, the horizontal component of the velocity would be smaller and so this line would start at zero still but would have a smaller, but still positive, slope.*	
		Total for part i. 3 points
		Total for Question 1 15 points

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Question 2: Paragraph Argument Short Answer — 10 points

a.

For indicating that the disk has a greater speed as it leaves the right end of ramp 2 because more potential energy was converted to kinetic energy. **1 point**

For stating that disk on ramp 2 will not go as high because it will have less potential energy (or disk on ramp 1 has more potential energy) due to conservation of mechanical energy **1 point**

OR

For stating that disk on ramp 2 will not go as high because disk on ramp 2 has a lower vertical velocity (or disk on ramp1 has a higher initial vertical velocity).

Example response for part a.

The disk has a greater speed when leaving the right end of ramp 2. A greater speed and smaller launch angle means that the horizontal velocity component at launch is greater for the disk on ramp 2. So the disk launched from ramp 2 will have a greater kinetic energy at the apex, and therefore less potential energy (in the disk-Earth system) and a lower height.

Total for part a. 2 points

b.

For indicating that the speed of the disk on the flat section is less for ramp 3 since less potential energy has been converted to kinetic energy. **1 point**

For indicating the flat section of the ramp is longer in ramp 3, so there is a greater distance to travel. **1 point**

For concluding that since the speed on the flat section of ramp 3 is less and the distance is greater, the time must be greater as well. **1 point**

Example response for part b.

For ramp 3, the change in potential energy of the disk-Earth system is less, so the disk has less kinetic energy and thus less speed on the flat section. Since the flat section of ramp 3 is also longer, and the disk is moving more slowly, the disk will spend more time on the flat section of ramp 3 than on the flat section of ramp 1.

Total for part b. 3 points

c.

For correctly identifying the collision with the ceiling at time t_R **1 point**

For stating that a collision with the ceiling will exert a force on the ball, accelerating it **1 point**

OR

For saying that the force changes the vertical velocity of the ball

OR

For saying that the direction of the vertical velocity changes

For correctly identifying the collision with a wall at time t_c **1 point**

For stating that a collision with the wall will exert a force on the ball, accelerating it **1 point**

OR

For saying that the force changes the horizontal velocity of the ball

OR

For saying that the direction of the horizontal velocity changes

For a logical, relevant, and internally consistent argument that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response **1 point**

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Example response for part c.

Each surface exerts a normal force; thus, the ceiling and floor exert vertical forces and the walls exert horizontal forces. When a net force is applied, there is an acceleration and a change in velocity. Thus, when there is a horizontal force exerted by the wall there is a change in the horizontal velocity, which happens at time t_c, so the ball collides with the wall at t_c. When the vertical velocity changes from positive to negative at time t_B, there is a downward force, which only happens when the ball collides with the ceiling. So the ball collides with the ceiling at t_B.

Total for Question 2 10 points

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Section I: Multiple-Choice Question

1. 参考答案：A

考察 Uni2 中 Dynamic 中 Newton's Law 知识点。

题干说一个从上掉落的小物块 Y 和一个质量相同的连接弹簧的小物块 X 碰撞并粘到一起。问当碰撞发生后到两个小物块短暂静止时，Y 对 X 的力 F_{down} 与 X 对 Y 的力 F_{up} 以及 y 的重力 m_yg 的大小关系。

因为此时并不是真正的平衡状态，只是短暂的静止，可以判断出此时处于两个小物块所能到达的最低点，此时瞬时速度减少为零，加速度向上达到最大值。

根据牛顿第二定律，此时加速度向上所以 y 受到 x 的力 F_{up} 大于重力 m_yg；而根据牛顿第三定律，Y 对 X 的力 F_{down} 与 X 对 Y 的力 F_{up} 是一对相互作用力，两者等大所以选 A

2. 参考答案：D

考察 Uni1 中 Kinematics 中 Acceleration 知识点。

题干说小物块从一个斜面滑下，斜面上有三处不可忽略摩擦的地方，如阴影所示。问测量哪项能够估算出小物块在中点时的加速度。

要计算瞬间加速度有两条途径，或者通过瞬间速度变化率或者通过牛顿第二定律分析合外力求出。 只有 D 选项是通过前后瞬时速度的变化量和中间时间可以求出短时间内平均加速度近似等于瞬间加速度。

A 选项总路程和总时间只能算出平均速度；B 选项最终速度和运行时间算不出；C 选项前后两点距离和通过时间只能算出中点的平均速度。

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3-5 题为一个图

题干意思：重量为 0.2kg 的小物块从高度 H 处在一个忽略摩擦的弧面滑动从图二的位置距离地面 0.40m 处以 3.0m/s 与地面 30 度的夹角离开。

3. 参考答案：C

考察 Uni4 中 Energy 中 Conservation of Mechanical Energy 知识点。

题干如上。问 H 的高度最接近?

要计算高度 H 可以通过能量守恒中动能的增加量等于重力势能的减少量来计算，即 1/2m（v^2-v_0^2）=mg（H-h_2）计算，其中 m 为质量 0.2kg，v 是 3.0m/s，v_0 是 0m/s，g 取 10m/s^2，h_2 是 0.4m。

算出 H 等于 0.85m，C 最接近。

4. 参考答案：A

考察 Uni7 中 Circular Motion 中 Uniform Circular Motion 知识点。

题干说小物块受到的重力大小是 F_g 支持力大小是 F_n，问在最低点两者大小关系。

在最低点小物块向合外力向上，重力 F_g 小于支持力 F_n 所以选 A。

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5. 参考答案：C

考察 Uni2 中 Dynamic 中 Projectile Motion 知识点。

题干如上，问小物块从弧面离开后达到最高点的速度。

达到最高点时小物块竖直速度为 0，水平速度不变，所以求出离开时水平速度即可。

$V_x=V\cos30=2.6m/s$

6. 参考答案：AD

考察 Uni5 中 Momentum 中 Center of Mass 知识点。

题干说两人在火车上面对面坐着，火车速率是 v，问关于两人质心速率的说法哪两个选项是正确的。

题目考了关于质心的理解，就是把两个人看作一个整体，这个系统的速度和两个人的速率都是 v，系统内部无相对运动，对于地面三者都是速率 v。A 选项说和人 1 相对速率是 0，D 选项说相对速率是 v。

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7. 参考答案：AB

考察 Uni3 中 Circular Motion 中 Gravitation 知识点。

题干说一个宇航员想测量木星的质量，假设木星卫星的轨道是圆形。问选择哪两个物理量能计算出木星的质量?

要计算出木星的质量要结合引力和圆周运动的公式，可以通过公式 $T^2=4\pi^2r^3/GM$，$v=\sqrt{GM/r}$，以及 $\omega=\sqrt{GM/r^3}$ 来算出木星质量。

A 选项通过 v 和轨道半径 r 可以求出 M，B 选项可以通过周期 T 和速率 V 求出轨道半径 r（$T=2\pi r/v$），再通过 v 和轨道半径 r 求出 M。CD 求不出。

8. 参考答案：BD

考察 Uni1 中 Kinematics 中 Acceleration 知识点。

题干说两个物体沿着水平直线运动，图中显示了两个物体在相同时间内的速度-时间图像。问两个物体在这个区间内什么量是相同的

分析图能够看出来两幅图斜率一样所以加速度一致，速度的变化量也一致，所以选 BD

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Section II: Multiple-Choice Question

1. 参考答案：B

考察 Uni4 中 Energy 中 Conservation Of Energy 知识点。

题干说小物块从静止 A 点被弹簧推到 B 点，经过无摩擦轨道后到达相同高度点 C。问从 A 到 C 点的小物块-地球系统的重力势能和小物块动能的变化。

重力势能的变化只要看高度的变化量就可以，A 到 C 高度不变，重力势能不变。动能的变化要看有没有外力做功，A 到 C 弹簧弹力做正功，动能增加。所以选 B

2. 参考答案：D

考察 Unit4 中 Energy 中 Work 知识点。

题干说一个人对小物块施加向上的力，小物块不确定是向上运动还是向下或者都不是。问那个选项中运动情况和这个向上的力做的功是匹配的?

力和运动同向做功为正，反向为负，垂直的话不做功。D 选项向下运动做负功正确。

A 选项不运动，力不做功；B 选项向上运动做正功；C 选项向下运动做负功。

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3. 参考答案：A

考察 Uni3 中 Gravitation 中 Gravitational Force 知识点。

题干说两个卫星环绕地球旋转。卫星 1 质量是 m_0 轨道半径是 $2R_E$,R_E 是地球半径。卫星 2 质量是 $2m_0$ 轨道半径是 $3R_E$。问两个卫星受到的引力和飞行速率的大小

要计算引力和速度可以用公式 $F=Gm_1m_2/r^2$ 和 $v=\sqrt{GM/r}$ 计算。对比之下，F1 大于 F2，v1 大于 v2，所以选 A

4. 参考答案：C

考察 Uni2 中 Dynamics 中 Projectile Motion 知识点。

题干说如图一个石盘在冰面上以 v 的速度向西滑动，一个小孩用一个橡皮锤在 x 点向圆心方向打击石盘，每半秒敲击一次，持续 10s 但是没有导致石盘旋转。问哪个选项更接近圆盘的路径。

整个运动过程中水平方向速度不变，竖直方向上进行加速，那么可以类比抛物运动，这个是一个加速度向上的抛物运动，应该选择 C 选项。

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Section III: Free-Response Question

1. 题目：一个盒子放在一个按压的弹簧前，弹簧推着盒子走了一段距离，盒子沿斜坡向上有足够速度离开斜坡，离开斜坡后运动到最高点然后下落。假设盒子与空气和轨道间无摩擦。

重复这个场景，用一个更硬弹簧常数 k 更大的一个弹簧，还是压缩到相同距离 x 并且使用相同的盒子。

Part a.

考察： unit4 energy 中机械能守恒

题目： 不用数字公式解释清楚更硬的弹簧是如何让盒子达到更高的最高高度

解析： 从能量角度角度更简单一些，想要达到更高的高度意味着获得更多重力势能，重力势能来自动能转化，然后再来自于弹簧弹性势能给予的。

从力的角度就是弹力更大，相同的加速位移会获得更大速度，小盒子获得更大速度才能冲的更高。

采分点和示例：

a. For a statement that with a stiffer spring the spring constant would increase (or the average force would increase), so the speed of the box as it leaves the spring will be larger

1 point

For a statement that because the speed of the box as it leaves the spring will be greater, and everything else remains the same, the maximum height of the block will increase

1 point

Example response for part a.

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A stiffer spring means that the spring constant is larger, which means that there is more initial energy stored in the spring (or that the average net force on the box is greater), which means that the launch speed is greater, so with everything else the same the box will reach a larger maximum height.

Total for part a. 2 points

Part b.

考察： unit4 energy 中机械能守恒

题目： 学生给出了一个未知对错的公式，是不是和你在 part a 中的解释一致，并解释

解析： 这个公式把 Mg 移到左边时就是重力势能与弹性势能的关系式，公式题目一般是按物理量变化趋势来判断和解释。

采分点和示例：

For indicating "yes", with an attempt at a justification using functional dependence **1 point**

For indicating that, since k is in the numerator if *k* increases, *h* will increase **1 point**

Example response for part b.

Yes, it is consistent with my reasoning – since k is in the numerator, if k increases, h will also increase.

Total for part b. 2 points

此时题目再次发生变化：两个学生对于盒子到达最高点时的运动情况提出了自己的看法

学生 1：盒子最高点的速率是 0 因为在最高点时动能最小。

学生 2：最高点时只有速度的竖直分量是 0，因为在最高点加速度的竖直分量是 0。

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Part c 和 d

考察： unit1 kinematics 中抛物运动

题目： c：学生 1 的话语有对的地方吗？d：学生 1 说的有错的地方吗？

解析： 学生 1 从能量角度考虑，首先我们知道这是一个初速度斜向上的抛物运动，那么水平速度不变竖直速度先减小后增加，整体是动能转换成重力势能，重力势能再转换成动能，所以最高点速率不为零，但是最高点的动能确实最小。

采分点和示例：

c. For a correct statement and no incorrect statements **1 point**

Example responses for part c.

Student 1 is correct in saying that the kinetic energy is a minimum at the top of the trajectory.

OR

The second statement

d. For an incorrect statement and no correct statements **1 point**

Example responses for part d.

Student 1 is incorrect in saying that the speed of the block is zero at the max height

OR

The first statement

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Part e 和 f

考察： unit1 kinematics 中抛物运动

题目： e：学生 2 的话语有对的地方吗？f：学生 2 说的有错的地方吗？

解析： 学生 2 从加速度角度考虑，一个初速度斜向上的抛物运动，那么水平速度不变竖直速度先减小后增加，水平方向上没有加速度，而竖直方向上加速度一直是 g 没变。

采分点和示例：

e. For a correct statement and no incorrect statements **1 point**

Example response for part e.

Student 2 is correct in saying that only the vertical component of the speed is zero at the max height

OR

The first statement

f. For an incorrect statement and no correct statements **1 point**

Example response for part f.

Student 2 is incorrect in saying that the vertical component of the acceleration is zero at the top of the trajectory.

OR

The second statement

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Part g.

考察：unit4 energy 中能量守恒

题目：把弹簧和盒子当做一个系统，但是不考虑地球，比较弹簧完全压缩和盒子落地前瞬间的能量大小关系

解析：此时盒子和弹簧是一个系统，那么外力就是支持力和重力（不计摩擦），两个过程对比，支持力一直垂直运动方向不做功，盒子竖直方向上没有发生位移因此重力也不做功

采分点和示例：

g. For indicating that the energy of the box/spring system remains the same **1 point**

For indicating that there is mechanical energy in the spring **1 point**

OR

For indicating that the box returns to the same height

For indicating that just before the box lands all that energy is again kinetic energy, and none is lost

1 point

OR

For indicating that the net work done by gravity is zero

Example responses for part (g)

The energy of the spring-box system initially is spring potential energy, and just before the box lands, all the energy is kinetic energy, and because there is no net work done by outside forces, the energy of the spring-box system is the same.

OR

The energy of the spring-box system remains the same because the box returns to the same height, and so the net work done by gravity is zero.

Total for part g. 3 points

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Part h.

考察：unit4 energy 中能量守恒

题目：如果盒子和轨道间摩擦不可忽略，提出一个改变设定物理量的方式让现在所能达到的最大高度和初始设定时最大高度相同。

解析：此时有摩擦了，那么还想要达到相同的高度，重力势能不变，但是这个过程摩擦力做功，因此损失的能量会增多，也就需要更多的初始机械能，可以考虑弹簧增加更多弹性势能。

采分点和示例：

h. For indicating a valid change that could be made so that the maximum height would be the same

1 point

Example response for part (h)

Nonnegligible friction would cause mechanical energy to be dissipated. Therefore, the compression distance could be increased so that the spring transfers more energy to the box, offsetting the loss in energy from friction.

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Part i.

考察：unit1 kinematics 中抛物运动

题目：这个题目给了一个盒子在空中的水平位移随时间变化的图像，问题是这个图像的斜率怎样才能变化？如果能变化的话，让斜坡角度增大但是小于 90 度，轨道末的高度还是一样吗？

解析：图像的斜率是水平位移除以时间，即水平速度，可以看到水平速度会随斜坡角度增大而减小，v 水平=v 离开斜坡 cosø。

采分点和示例：

i. For indicating that the slope of the line would be smaller **1 point**

For indicating that with a larger angle, the horizontal component of the initial velocity is smaller

1 point

For indicating that the slope of the horizontal position as a function of time graph is equal to the horizontal velocity of the box

1 point

Example response for part i.

Since the graph is of horizontal position as a function of time, the slope of the line represents the horizontal velocity as a function of time. If the box were launched at a larger angle, the horizontal component of the velocity would be smaller and so this line would start at zero still but would have a smaller, but still positive, slope.

Total for part i. 3 points

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2. 题目：物理课上同学们用一系列实验器材研究抛物运动，假设空气因素忽略。一组组装了如斜坡一所示的长斜坡，左侧释放右侧离开，斜坡摩擦可忽略。

斜坡 2：学生们又在左边斜坡不变的情况下把右边斜坡变矮了，右边斜坡的长度不变。

Part a.

考察： unit4 energy 中能量守恒

题目： 斜坡 2 与斜坡 1 相比，圆盘离开斜坡后达到的最高高度的变化?

解析： 首先两个斜坡初始重力势能相同，都没有摩擦消耗能量，那么盘子在离开斜坡 2 时的动能更大，重力势能更小，而且这个速度会更靠近水平方向上，那么所能达到的高度自然就会减小。

采分点和示例：

a. For indicating that the disk has a greater speed as it leaves the right end of ramp 2 because more potential energy was converted to kinetic energy.

1 point

For stating that disk on ramp 2 will not go as high because it will have less potential energy (or disk on ramp 1 has more potential energy) due to conservation of mechanical energy

OR

For stating that disk on ramp 2 will not go as high because disk on ramp 2 has a lower vertical velocity (or disk on ramp1 has a higher initial vertical velocity).

1 point

Example response for part a.

The disk has a greater speed when leaving the right end of ramp 2. A greater speed and smaller launch angle means that the horizontal velocity component at launch is greater for the disk on ramp 2. So the disk launched from ramp 2 will have a greater kinetic

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energy at the apex, and therefore less potential energy (in the disk-Earth system) and a lower height.

Total for part a. 2 points

Part b.

考察： unit2 dynamics 中斜坡类型的问题

题目： 斜坡 3 与斜坡 1 相比，水平部分更加高了。在斜坡 1 和斜坡 3 上，圆盘在哪个上的水平部分花费时间更久？

解析： 圆盘的初始释放位置和左侧斜坡的加速度都是相同的，但是斜坡 3 上圆盘的加速距离更短，那么到达水平部分的速率也会更小，同时斜坡 3 的水平部分也更长，自然花费时间更长。

采分点和示例：

b. For indicating that the speed of the disk on the flat section is less for ramp 3 since less potential energy has been converted to kinetic energy.

1 point

For indicating the flat section of the ramp is longer in ramp 3, so there is a greater distance to travel.

1 point

For concluding that since the speed on the flat section of ramp 3 is less and the distance is greater, the time must be greater as well.

1 point

Example response for part b.

For ramp 3, the change in potential energy of the disk-Earth system is less, so the disk has less kinetic energy and thus less speed on the flat section. Since the flat section of ramp 3 is also longer, and the disk is moving more slowly, the disk will spend more time on the flat section of ramp 3 than on the flat section of ramp 1.

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Total for part b. 3 points

Part c.

考察：unit5 momentum 中弹性碰撞类型的问题

题目：一组用了发射钢球设备。钢球在天花板，地面和墙壁上无顺序的反弹，每一次都是弹性碰撞，无摩擦。表中显示了一段时间内水平速度和竖直速度随时间的变化，向上为正。图表这段时间内钢球发生两次弹性碰撞，确定两次的时间，并解释你如何知道每次是与天花板，地面和墙壁哪个发生了碰撞。

解析：发生碰撞必然意味着速度的剧烈变化，那么能够看出 tb 和 tc 时刻发生了碰撞，在 tb 时刻，只有竖直速度发生从正到负，那就只能是和天花板，在 tc 时刻，水平速度剧烈改变，竖直速度恒定向下增加，所以应该是与墙壁发生碰撞。

采分点和示例：

c. For correctly identifying the collision with the ceiling at time t_R **1 point**

For stating that a collision with the ceiling will exert a force on the ball, accelerating it

OR

For saying that the force changes the vertical velocity of the ball

OR

For saying that the direction of the vertical velocity changes

1 point

For correctly identifying the collision with a wall at time t_c **1 point**

For stating that a collision with the wall will exert a force on the ball, accelerating it **1 point**

OR

For saying that the force changes the horizontal velocity of the ball

OR

For saying that the direction of the horizontal velocity changes

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For a logical, relevant, and internally consistent argument that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response.**1 point**

Example response for part c.

Each surface exerts a normal force; thus, the ceiling and floor exert vertical forces and the walls exert horizontal forces. When a net force is applied, there is an acceleration and a change in velocity. Thus, when there is a horizontal force exerted by the wall there is a change in the horizontal velocity, which happens at time t_c, so the ball collides with the wall at t_c. When the vertical velocity changes from positive to negative at time t_B, there is a downward force, which only happens when the ball collides with the ceiling. So the ball collides with the ceiling at t_B.

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