AP® Physics 1 Practice Questions - 2020 Exam Format

The AP® Physics 1 Exam this year is being designed specifically for an at-home administration, so points will not be earned from content that can be easily found in textbooks or online.

The exam will consist of two free response questions.

- Question 1 will be a Qualitative/Quantitative Translation (QQT) question. Such questions are designed to assess students' ability to translate between quantitative and qualitative justification and reasoning.
- Question 2 will be a Paragraph-Length Response Short Answer (paragraph) question. Such questions are designed to assess students' ability to create a paragraph-length response, which consists of a coherent argument about a physics phenomenon that uses the information presented in the question and proceeds in a logical, expository fashion to arrive at a conclusion. More information about these questions can be found on the College Board website.

Students will have 25 minutes to read and respond to Question 1, and then 5 minutes to upload their response. After uploading the response to Question 1, students will have 15 minutes to respond to Question 2, with 5 additional minutes to upload their response to Question 2. Once their response to Question 1 has been submitted, they cannot go back to it. Given the time allotment and the percentages College Board has stated for each question, it would be reasonable to assume the paragraph question, at least, will be a little longer than typical for the P1 exam.

Typically, with 5 questions to demonstrate their understanding on an exam, the points on an AP® Physics 1 exam are what the committee called “fat”, each demonstrating something significant. With slightly extended time for these two problems, I would imagine them being worth a few more points, and because of there being limited opportunities to demonstrate understanding, perhaps a few “skinnier” points being available.

Students will need the AP® Physics 1 equation sheet and should access and/or print it before the exam. Remind them they won’t need everything on it. It is to keep them from having to memorize, but they should still recognize the things with which they are supposed to be familiar. The questions will be designed such that required calculations can be done with a pencil and paper. However, use of a calculator is allowed and may be helpful. Simple (“four-function”) calculators are freely available as apps for computers and phones. Students should ensure that if they want to use such an app, it is installed before the exam.

I have provided one practice QQT question and four practice paragraph questions. The QQT coupled with any **one** of the paragraph question examples provided probably represents about the correct amount of work for the planned AP® Physics 1 Exam.

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However, these two questions alone do not cover the full breadth of units 1-7, which will be the content of this year's exam. Teachers were mentioning to me that good paragraph questions with rubrics are in short supply, so I wanted to create a few more of those across some topics that students sometimes find difficult. While I beefed up the paragraph questions to 8 points to make the percentages right, I kept the rubric closer to the usual style of fat points so they will still be useful in non-pandemic years.

The list of learning objectives (LOs) for some of the questions is slightly ambiguous as there is more than one way to solve the problem, but the College Board faces the same issue.
Question 1 includes LO's 2.B.1.1; 3.A.2.1; 3.A.1.1; 3.A.3.1; 3.B.1.1
Question 2 includes LO's 1.A.5.2; 3.A.3.1; 3.B.1.1; 5.B.2.1; 5.B.3.1
Question 3 includes LO's 4.A.1.1; 4.A.3.2; 5.B.3.3; 5.B.4.1; 5.D.1.1; 5.D.2.1; 5.D.2.5; 5.D.3.1
Question 4 includes LO's 2.B.1.1; 3.A.1.1; 3.B.1.1; 3.E.1.1; 5.B.1.2; 5.B.4.1; 5.B.5.4
Question 5 includes LO's 3.A.1.1; 3.A.3.1; 3.E.1.3; 5.B.4.1; 5.B.5.4; 5.D.2.3; 5.D.2.5

(see following page for problems)

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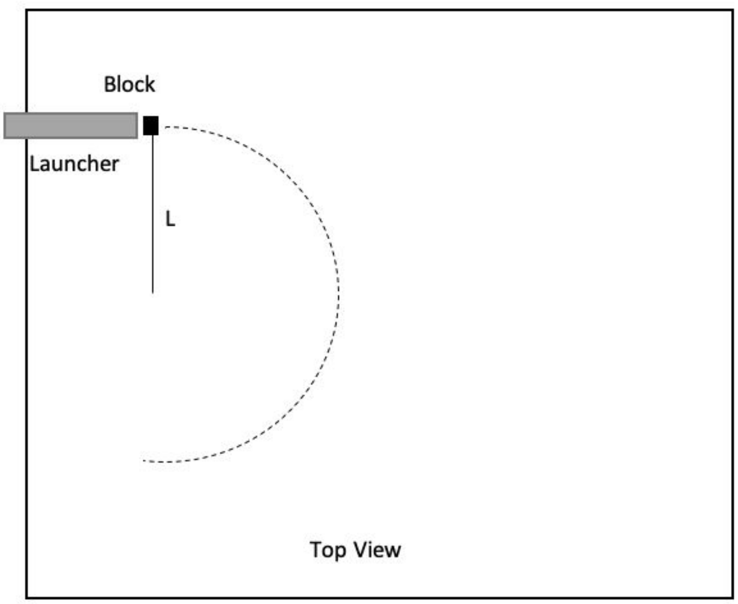
1. **(60%, 25 minutes)** ***QQT***
   Students are to carry out a series of experiments with blocks in a lab. For the first experiment, some students decide to use a launcher to give both blocks the same initial velocity, $\boldsymbol{v}_0$, and launch them across a table. The coefficient of friction between the table and the blocks is μ. The blocks are made of the same material, but the mass of block A (m_A) is twice the mass of block B (m_B).
   a. i. Student 1 says block A will slide farther along the table before coming to rest. What reasoning would support this prediction? (Do not use an equation; state the reasoning conceptually.)
   ii. Student 2 says block B will slide farther. What reasoning would support this prediction? (Do not use an equation; state the reasoning conceptually.)
   b. Derive a mathematical expression you could use to find the distance traveled by block A after it leaves the launcher, in terms of given quantities and physical constants.
   c. Does the expression you derived in (b) support the reasoning you used in part (a) to support either Student 1 or Student 2, or both? Explain briefly.



   d. In a second experiment, you decide to connect a string which has length **L** from a pivot to the side of block A (which has width *d*) so that the block will be constrained to go in a circular path about the pivot once it leaves the launcher.
   i. Write an equation for the maximum tension in the string during the motion in terms of the given variables and relevant physical constants and justify its choice and the variables used.
   ii. Qualitatively describe how the tension in the string changes during the motion and explain.

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2. **(40%, 15 minutes)** ***Paragraph Example 1***
   A student throws a small rubber ball at a brick wall. The ball is thrown, leaving the person's hand at approximately shoulder height, at an angle above the horizontal. The ball strikes the wall at the moment when its velocity is horizontal. The ball bounces off the wall and strikes the ground some distance from the wall.
   a. Is the object model appropriate for analyzing the motion of the ball for the entire time from when it leaves the thrower's hand until it strikes the ground? Briefly justify your answer.
   b. In a clear, coherent, paragraph-length response, describe the motion of the ball from the instant after it is released until it hits the ground. Take your system to be just the ball and neglect air resistance. Be sure to address the position, velocity, acceleration and energy of the system in your description and justify your description with reasoning based on physics principles.

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3. **(40%, 15 minutes)** ***Paragraph Example 2***
   Two identical carts are set up to collide on a track in a physics classroom. Assume you may neglect friction between the carts and the track. Motion detectors are set up to measure the velocity of each cart both before and after the collision. The bumpers on the carts can be adjusted to change the elasticity of the collision.

   Three trials at different elasticity settings for the same initial velocities result in three different final conditions.
   - In Trial A, the two carts come to rest as a result of the collision.
   - In Trial B, the two carts bounce off each other and exchange velocities.
   - In Trial C, the two carts bounce off each other and move with lower speeds than they had before the collision.

   In a clear, coherent, paragraph-length response, identify the types of collisions associated with Trials A, B, and C. For each trial, describe the center-of-mass velocity before, during and after the collision. Also describe any energy changes during the interaction, clearly listing the objects in your system.

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4. **(40%, 15 minutes)** ***Paragraph Example 3***
   A device is used to launch objects from the edge of a platform, 5.0 meters above the ground. To determine the speed with which the device launches the objects, you set up a motion detector to measure the final speed with which the objects strike the ground. You realize you do not know if the device is set to launch the objects vertically upward or vertically downward.
   a. One student argues that in order to find the launch direction you would need to observe the initial direction of motion of the object. In a clear, coherent, paragraph-length response, describe why the student may believe this, and if you agree or if there is another option. Define your system and support your argument with a detailed description of the motion of a launched object for both an upward and a downward launch.
   b. In another trial, the launcher was set to launch the object horizontally from the same initial position. How do the final velocity and speed of the object compare to that of the object launched vertically downward? Justify your answer.

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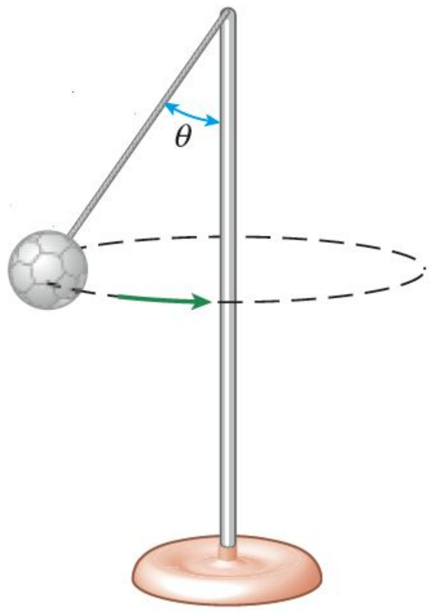
5. (40%, 15 minutes) ***Paragraph Example 4***



Two students are playing a game called tetherball, where a ball is connected by a rope to the top of a vertical pole so that it can move around the pole, as shown in the figure.

a. As the ball passes directly in front of the pole, such that it is moving to the right, it collides head on with a small ball, thrown at it softly by a third student. In a clear, coherent, paragraph-length response, describe the motion of the ball attached to the rope after the collision, compared to the motion before the collision.

b. At another time, as the ball passes directly in front of the pole, such that it is moving to the right, it collides head on with, and sticks to, a small lump of clay, thrown at it softly by a third student. The rope breaks at the same instant the clay collides with the ball. Describe the motion of the ball-clay system after the collision, compared to the motion of the ball before the collision. Justify your answer.

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Scoring Guide/Solutions

Question 1

12 points total | **Distribution of points**

(a) 2 points

i. 1 point

For correctly relating inertia to resistance to change in motion — 1 point

Example:

Block A has a greater inertia, so it will resist slowing down more

ii. 1 point

For correctly relating decreased friction force to change in motion — 1 point

Example:

The floor will exert a smaller friction force on block B, so its motion will change more slowly

(b) 3 points

For using Newton's second law in one dimension, parallel to the table's surface, either explicitly or implicitly, to correctly relate $\mathbf{F}_{net}$ to **a**. — 1 point

For using Newton's second law (or reasoning in terms of zero net force) in one dimension, perpendicular to the board's surface, either explicitly or implicitly — 1 point

Note: Replacing the normal force with *mg* is "implicit" use of Newton's second law in the perpendicular direction for a horizontal surface.

For using an appropriate kinematic relationship to correctly find the distance travelled in terms of given quantities and fundamental constants — 1 point

Example:

$\boldsymbol{F}=m\boldsymbol{a}$, assume the initial motion is in the $+x$ direction. Then $\boldsymbol{F}=m\boldsymbol{a}$ is $F_x = ma_x = -\mu mg$ (The m can be either m_A or m_B.) So, $a_x = -\mu g$.

Using kinematics:

$\Delta x = v_0\Delta t + {}^1/_2 a_x(\Delta t)^2$

To find Δt, $v_f = 0 = v_0 + a_x\Delta t$ so $\Delta t = (0-v_0)/(-\mu g) = v_0/\mu g$

$\Delta x = v_0(v_0/\mu g) + {}^1/_2 (-\mu g)(v_0/\mu g)^2 = {}^1/_2\, v_0^2/\mu g$

(c) 2 points

For a correct connection to acceleration being inversely related to inertia, and distance is determined by acceleration — 1 point

For a correct connection of force directly related to mass — 1 point

Example:

The acceleration does not depend on *m*. The net force on a block directly depends on the mass of the block, but the acceleration is proportional to the force and inversely proportional to the mass, so the acceleration does not depend on the mass of the block.

(d) 5 points

i. 3 points

For correctly relating tension to the needed centripetal force and using the correct form of the centripetal force — 1 point

For correctly finding the radius of the motion — 1 point

For justifying that the maximum centripetal force will occur for the maximum velocity, which is the initial velocity. — 1 point

Example:

$F_T = F_c = mv_0^2/r$. The radius of the motion is the distance from the pivot to the center of mass, so $r = d/2 + L$. The tension in the string provides the centripetal force and will be greatest when the speed is largest.

ii. 2 points

For correctly stating that the tension will decrease — 1 point

For explaining why the needed centripetal force decreases — 1 point

Note: the explanation of the decrease of the centripetal force could have been given in i.

Example:

The tension in the string will decrease because as the block slows down, the amount of force needed to keep it going in a circle decreases. The direction of the object does not need to be changed as fast to keep a slower moving object on a circular path.

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Question 2

9 points total | **Distribution of points**

(a) 2 points

For stating a feature required to use the object model — 1 point
For correctly relating the stated feature to the scenario — 1 point

Example:
In order to bounce off the wall, the ball must store internal energy during the collision. An object can only have kinetic energy, so the ball cannot be modelled as an object during the collision with the wall.

(b) 7 points

For using Newton's second law in one dimension, perpendicular to Earth's surface, either explicitly or implicitly, to correctly describe motion in the vertical direction — 1 point
For using Newton's first law (or reasoning in terms of zero net force) in one dimension, parallel to Earth's surface, either explicitly or implicitly to correctly describe the horizontal motion — 1 point
For stating that the ball is at its maximum height when it strikes the wall since the vertical component of velocity is zero — 1 point
For a correct statement that the kinetic energy of the ball changes as it is in flight due to work done by the force of gravity exerted by Earth on the ball or because speed changes, but no credit if say it is due to gravitational potential energy changes — 1 point
For a correct statement that the ball compresses when it hits the wall, converting kinetic energy to internal energy, and that it converts some of that energy back into kinetic energy as it leaves the wall. — 1 point
For a statement that the ball is going faster vertically when it hits the ground because it is lower than when it was thrown (full credit for this even if they missed the possible change in horizontal speed at the wall). — 1 point
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:
The ball has initial velocity in the horizontal and vertical directions. The component of velocity in the horizontal direction does not change, but the vertical component decreases as the ball goes up because of the acceleration due to gravity. Since its speed decreases, its kinetic energy decreases. When it hits the wall, it is at its highest point since its velocity is purely horizontal (the

vertical velocity is zero). The ball's kinetic energy is converted to internal energy in the collision with the stationary wall. If the internal energy is all potential energy, it will bounce back with the same horizontal speed, but in the opposite direction. If some of the internal energy is dissipated energy, then it will leave the wall slower than it struck it. The ball will keep this constant horizontal velocity, and its vertical velocity will increase downward and its kinetic energy will increase. Since it lands lower than it starts, it will have a larger vertical speed when it hits the ground.

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Question 3

9 points total	Distribution of points
Center of mass velocity is constant unless an external force is exerted on the system	1 point
Momentum is always conserved, since we can neglect friction it is constant	1 point
For all three cases the center of mass velocity is the same This can be implied by stating the momentum is the same	1 point
For a correct statement that the kinetic energy changes into other types of energy during a collision	1 point
For a correct use of concept that amount of kinetic energy not restored determines collision type	1 point
For a correct statement that in elastic collisions all kinetic energy energy is restored.	1 point
For a statement that during inelastic collisions some of the internal energy is converted into other types of energy (or could say dissipated)	1 point
For correctly finding the center-of-mass velocity	1 point
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:

There are three collisions described. In each case the initial velocities of the two identical carts are the same, so the initial kinetic energy, momentum and center-of-mass velocity of the system are the same for all three cases. Since momentum is always conserved, and we are told we can neglect friction, the momentum during and after the collisions will be the same as the initial momentum in all three cases, as will the center-of-mass velocity. In case A, the two carts collide and stop. Since momentum must be conserved and momentum is zero after the collision, the center-of-mass velocity was zero. This collision is totally inelastic since none of the kinetic energy stored in internal energy during the collision is restored. All of the internal energy is converted into other types of energy, such as warmth and sound. In case B, the two carts exchange velocities, so all the initial kinetic energy turned into potential energy and then is restored. This is an elastic collision. In case C, less kinetic energy is restored, but some still is (the case where they are moving slower), so it is an inelastic (but not totally inelastic) collision.

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Question 4

9 points total | **Distribution of points**

(a) 7 points

For using Newton's second law in one dimension, perpendicular to Earth's surface, either explicitly or implicitly, to correctly describe motion in the vertical direction or using gravitational potential energy of the Earth/object system or work done by force of gravity — 1 point

For stating that an object launched upward has a velocity of zero at its maximum height (or correct energy argument for same kinetic energy at launch height regardless of launch direction — 1 point

For using either kinematics or gravitational potential energy of the Earth/object system to explain that the object has the same velocity when it reaches Earth's surface for either launch direction — 1 point

For identifying time of flight as different for the two scenarios as another option — 1 point

For using a correct physics argument to relate their argument on whether or not there is another option, whether or not their other option or lack of an option was correct — 1 point

For identifying the correct system to support the argument used (Earth/object for gravitational potential energy, object only for work or Newton's laws) — 1 point

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:

If I take just the object as the system, I can use kinematics to describe the motion. An object traveling upward will go up until the acceleration due to gravity brings it instantaneously to a stop. Then it will begin to fall, again accelerating due to gravity, but now the acceleration is in the direction of motion, so it speeds up. The faster it is going when it is launched, the farther up it goes. It will gain that same speed as it falls back through the distance it travels upward, if air resistance can be neglected, so it will hit the ground with the same final speed as if it was launched downward at that same initial speed, which is probably why the other student holds this belief. However, it would not be necessary to observe the initial launch direction to tell the difference in these two cases, as the time to strike the ground will be different. An object launched directly downward will strike the ground in less time since it does not travel up and then back down.

(b) 2 points

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Change in gravitational potential energy of the Earth/object system is the same (or time for which it is accelerating is longer; or the component of the distance travelled in the direction of the force is the same so work is same) — 1 point

Final speed will be the same, but final velocity will be different, there is now a horizontal component — 1 point

Example:

This is most easily solved in using an energy approach, but with knowledge of the motion from kinematics. So, choose the Earth/object system. The object has the same initial kinetic energy and travels the same displacement closer to the Earth as in the downward launch so gains the same amount of additional kinetic energy from the decrease in gravitational potential energy so it will have the same final speed. The object's initial velocity is in the horizontal direction, and the component of velocity in the horizontal direction does not change. So, the object will have a smaller vertical component of its velocity when it hits the ground since the instantaneous speed is the magnitude of the velocity.

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Question 5

9 points total	**Distribution of points**
(a) 6 points	
For an indication that a head-on collision changes speed but not direction	1 point
For stating that when the ball slows down, the centripetal force needed to keep it moving in a circle decreases	1 point
For indicating that the tension in the rope supplies the centripetal force	1 point
For indicating that the horizontal component of the tension provides the centripetal force and the vertical component balances the force due to gravity so does not change	1 point
For stating that the angle the rope makes with the pole changes, correctly supported by some physics reasoning, even if a previous mistake is made	1 point
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:

The ball has initial velocity in the horizontal direction to the right. This velocity decreases because of the collision. Since its speed decreases, the centripetal force needed to keep it moving in a circle decreases. The forces on the ball before the collision are the tension exerted by the rope and the force of gravity. The vertical component of the tension must balance the force of gravity. Since the horizontal component provides the centripetal force the angle the rope makes with the pole will decrease since the horizontal component of the tension will decrease.

(b) 3 points

For correctly reasoning that this is a totally inelastic collision so kinetic energy and therefore speed decreases	1 point
For correctly reasoning that with no tension, ball will no longer move in a circle, its new horizontal velocity remains constant	1 point
For using Newton's second law (or reasoning in terms of changes in gravitational potential energy of the Earth/ball system to describe the subsequent motion in the vertical direction	1 point

Example:

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When the clay hits the tether ball, it is a totally inelastic head-on collision so the combination slows down. Since it is head on, it does not change the direction of the velocity, which was instantaneously to the right. Since the rope broke, there is no longer a force to keep the motion in a circle, so the ball will travel to the right, but also start falling downward due to gravity, now being in projectile motion. The horizontal component of velocity will stay constant and the vertical component will increase in magnitude until the ball hits the ground.