2017

AP CollegeBoard

AP Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

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AP® PHYSICS
2017 SCORING GUIDELINES

General Notes About 2017 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. The requirements that have been established for the paragraph length response in Physics 1 and Physics 2 can be found on AP Central at https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf.

3. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

4. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point, and a student's solution embeds the application of that equation to the problem in other work, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics; Physics C: Mechanics, Physics C: Electricity and Magnetism Course Description* or "Terms Defined" in the *AP Physics 1: Algebra-Based and AP Physics 2: Algebra-Based Course and Exam Description*.

5. The scoring guidelines typically show numerical results using the value $g = 9.8\ \text{m/s}^2$, but use of $10\ \text{m/s}^2$ is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

6. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

AP® PHYSICS 1
2017 SCORING GUIDELINES

Question 2

12 points total | **Distribution of points**

(a)

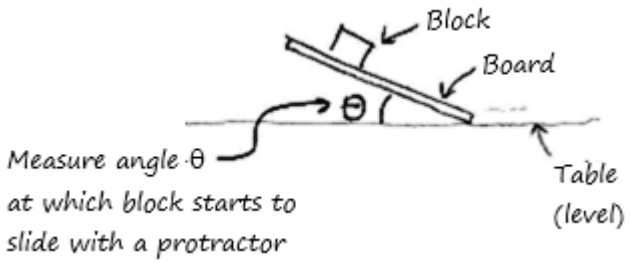
i. 3 points

For drawing a diagram of an experimental setup to measure the coefficient of friction that is feasible in a school physics lab — 1 point

For indicating the measurements necessary for calculating the coefficient of friction — 1 point

For indicating equipment necessary for measuring the quantities required to calculate the coefficient of friction — 1 point

Example:



ii. 3 points

For a description that is consistent with the diagram in part (a)(i), in enough detail that another student could replicate the experiment — 1 point

For a description that is a conceptually valid method to find quantities that would allow a calculation of a friction coefficient — 1 point

For including a valid method for reducing experimental error — 1 point

Example:

With the block at rest on the board, slowly lift one end of board until the block just begins to slide. Measure the angle between board and table and repeat several times with block at different locations on the board (with multiple trials at each location).

(b) 3 points

Note: In order to earn full credit for part (b), all terms (variables) must be indicated in the diagram and/or procedure of part (a).

For using Newton's second law (or reasoning in terms of zero net force) in one dimension, parallel to the board's surface, either explicitly or implicitly — 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 a tilted surface, the appropriate trigonometric term should be included.

For a correct derived expression of the coefficient of static friction in terms of quantities indicated in part (a) — 1 point

Question 2 (continued)

Distribution of points

(c) 2 points

Correct answer: "The static and kinetic coefficients are not equal."
Reasoning cannot earn credit if the incorrect selection is made.

For identifying group 5's results as outliers, or indicating the presence of an outlier — 1 point
For a conclusion that coefficients are not the same, justified by either removing the outlier or noting the coefficients are different for each group — 1 point

(d) 1 point

For a valid argument that indicates the coefficient of static friction is a property of the two surfaces, and is consistent with the selected answer — 1 point

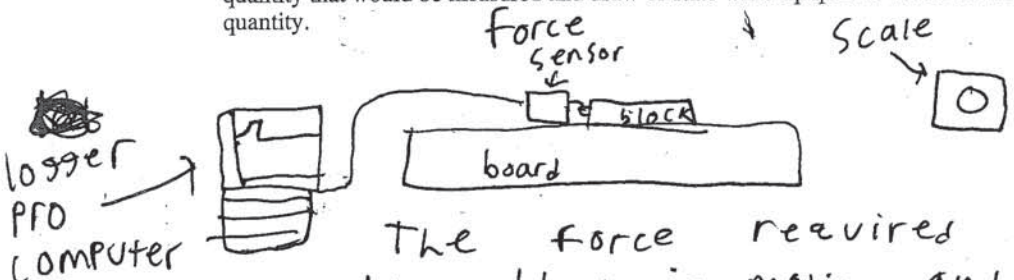
Example 1: Selects "Remain the same"
Referring to the equation in part (b), coefficient does not depend on mass.
Example 2: Selects "Remain the same"
The coefficient depends on the nature of the surfaces involved, not the masses or normal force of the objects involved.
Example 3: Selects "Decrease"
The increased normal force will cause smoothing of the surfaces, decreasing the coefficient of friction.
Example 4: Selects "Increase"
The increased normal force will cause the surfaces to become gouged, increasing the coefficient of friction.

2. (12 points, suggested time 25 minutes)

A student wants to determine the coefficient of static friction between a long, flat wood board and a small wood block.

(a) Describe an experiment for determining the coefficient of static friction between the wood board and the wood block. Assume equipment usually found in a school physics laboratory is available.

i. Draw a diagram of the experimental setup of the board and block. In your diagram, indicate each quantity that would be measured and draw or state what equipment would be used to measure each quantity.

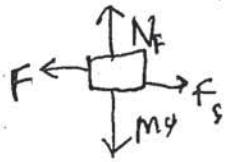


The force required to set the block in motion and the mass of the block would be measured

ii. Describe the overall procedure to be used, including any steps necessary to reduce experimental uncertainty. Give enough detail so that another student could replicate the experiment.

The student would first connect a force sensor to the logger pro interface. Next the scale would be used to find the mass of the small block. This block would the be placed on the board and the student would connect a force sensor. Then using the force sensor a small increasing amount of force would be applied until the block is set in motion. This force would be recorded.

(b) Derive an equation for the coefficient of static friction in terms of quantities measured in the procedure from part (a).



$\Sigma F = ma$ $\quad f_f \leq \mu N_F$ $\quad N_F$

$N_F = mg$

$f_s = F$ $\quad N_F \mu = F$

$mg\mu = F$

$$\frac{mg}{F} = \mu$$

A physics class consisting of six lab groups wants to test the hypothesis that the coefficient of static friction between the board and the block equals the coefficient of kinetic friction between the board and the block. Each group determines the coefficients of kinetic and static friction between the board and the block. The groups' results are shown below, with the class averages indicated in the bottom row.

Lab Group Number	Coefficient of Kinetic Friction	Coefficient of Static Friction
1	0.45	0.54
2	0.46	0.52
3	0.42	0.56
4	0.43	0.55
5	0.74	0.23
6	0.44	0.54
Average	0.49	0.49

(c) Based on these data, what conclusion should the students make about the hypothesis that the coefficients of static and kinetic friction are equal?

___ The static and kinetic coefficients are equal.

__✓__ The static and kinetic coefficients are not equal.

Briefly justify your reasoning.

The data points in group 5 are an outlier and should be retested If these data points are not used the averages are $F_k = .44$ and $F_s = .54$

(d) A metal disk is glued to the top of the wood block. The mass of the block-disk system is twice the mass of the original block. Does the coefficient of static friction between the bottom of the block and the board increase, decrease, or remain the same when the disk is added to the block?

___ Increase ___ Decrease __✓__ Remain the same

Briefly state your reasoning.

The frictional force can be defined as $\mu_s N = f_s$ when the disk is added the Normal force increases but the coefficient of friction stays the same. Coefficients of friction deal with the types of surfaces rubbing together not the wieght.

GO ON TO THE NEXT PAGE.

P1 Q2 B1

2. (12 points, suggested time 25 minutes)

A student wants to determine the coefficient of static friction between a long, flat wood board and a small wood block.

(a) Describe an experiment for determining the coefficient of static friction between the wood board and the wood block. Assume equipment usually found in a school physics laboratory is available.

i. Draw a diagram of the experimental setup of the board and block. In your diagram, indicate each quantity that would be measured and draw or state what equipment would be used to measure each quantity.

h= measured
θ= measured / calculated

ii. Describe the overall procedure to be used, including any steps necessary to reduce experimental uncertainty. Give enough detail so that another student could replicate the experiment.

1) Place block on top of board on one side.
2) Leaving the far end of the board (away from the block) on the table, raise the block side until the block begins to slide.
3) Once the block starts sliding, STOP raising your board.
4) Take measurements h and θ from the diagram above
5) Using your measurements and a force diagram, calculate the F_f at this point. This is your static frictional force
6) $F_f \leq \mu|F_N|$, using your normal force from the diagram, solve for μ.

(b) Derive an equation for the coefficient of static friction in terms of quantities measured in the procedure from part (a).

$F_f \leq \mu|F_N|$ Default Equation

$F_f = \mu|F_N|$ Set equal do to process of experiment

$\frac{F_f}{|F_N|} = \mu$ Solve for μ

GO ON TO THE NEXT PAGE.

P1 Q2 B2

A physics class consisting of six lab groups wants to test the hypothesis that the coefficient of static friction between the board and the block equals the coefficient of kinetic friction between the board and the block. Each group determines the coefficients of kinetic and static friction between the board and the block. The groups' results are shown below, with the class averages indicated in the bottom row.

Lab Group Number	Coefficient of Kinetic Friction	Coefficient of Static Friction
1	0.45	0.54
2	0.46	0.52
3	0.42	0.56
4	0.43	0.55
5	~~0.74~~	0.23
6	0.44	0.54
Average	0.49 94	0.49 54

(c) Based on these data, what conclusion should the students make about the hypothesis that the coefficients of static and kinetic friction are equal?

___ The static and kinetic coefficients are equal.

___ The static and kinetic coefficients are not equal.

Briefly justify your reasoning.

If you exclude the outliers in the data, the averages are not equal, therefore, in no results do static and kinetic friction coefficients equal the other.

(d) A metal disk is glued to the top of the wood block. The mass of the block-disk system is twice the mass of the original block. Does the coefficient of static friction between the bottom of the block and the board increase, decrease, or remain the same when the disk is added to the block?

___ Increase ___ Decrease ___ Remain the same

Briefly state your reasoning.

F_f doesn't increases because the block is now being pushed down more, so the F_N increases, causing the F_f to go up. However, the coefficient (μ) doesn't change do to the same materials being in contact.

$F_f = \mu |F_N|$

GO ON TO THE NEXT PAGE.

2. (12 points, suggested time 25 minutes)

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(a) Describe an experiment for determining the coefficient of static friction between the wood board and the wood block. Assume equipment usually found in a school physics laboratory is available.

i. Draw a diagram of the experimental setup of the board and block. In your diagram, indicate each quantity that would be measured and draw or state what equipment would be used to measure each quantity.

ii. Describe the overall procedure to be used, including any steps necessary to reduce experimental uncertainty. Give enough detail so that another student could replicate the experiment.

You could place the wood block on the wood board, then rub the block against the wood, creating friction. To find the coefficient of the friction, you would use the equation $F = \mu N$. μ stands for the coeffient of friction. F is force and F_N is normal force (N)

(b) Derive an equation for the coefficient of static friction in terms of quantities measured in the procedure from part (a).

$$\frac{F}{N} = \mu \frac{N}{N} \rightarrow \mu = \frac{F}{F_N}$$

A physics class consisting of six lab groups wants to test the hypothesis that the coefficient of static friction between the board and the block equals the coefficient of kinetic friction between the board and the block. Each group determines the coefficients of kinetic and static friction between the board and the block. The groups' results are shown below, with the class averages indicated in the bottom row.

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Average	0.49	0.49

(c) Based on these data, what conclusion should the students make about the hypothesis that the coefficients of static and kinetic friction are equal?

____ The static and kinetic coefficients are equal.

✓ The static and kinetic coefficients are not equal.

Briefly justify your reasoning. The static and kinetic coefficients aren't equal. Every lab group came up with data showing that the coefficient of kinetic friction is less than the coefficient of static friction, other than lab group 5. This lab group could be an outlier, because its the only one unlike the others. It's only a coincidence that the averages came out to be equal.

(d) A metal disk is glued to the top of the wood block. The mass of the block-disk system is twice the mass of the original block. Does the coefficient of static friction between the bottom of the block and the board increase, decrease, or remain the same when the disk is added to the block?

✓ Increase ____ Decrease ____ Remain the same

Briefly state your reasoning. The mass would increase and the mass is needed to find the coefficient of static friction, therefore, it would increase.

AP® PHYSICS 1
2017 SCORING COMMENTARY

Question 2

Overview

This question assessed learning objectives 2.B.1.1, 3.A.1.2, 3.B.1.1, 3.B.1.2, 3.B.1.3, 3.B.2.1, and 3.C.4.1. The responses to this question were expected to demonstrate the following:

- The ability to design an experiment, indicate measurements and equipment required, and describe a valid procedure.
- The ability to identify the forces acting on an object in contact with a surface and resolve all forces into components parallel and perpendicular to the surface.
- Understanding how to apply Newton's second law to an object in order to arrive at a coefficient of friction between two surfaces.
- Understanding how to differentiate between static friction and kinetic friction.
- Recognizing that the coefficient of friction describes only the properties of two surfaces in contact resulting from interatomic forces.

Sample: P1 Q2 A
Score: 10

Part (a) describes a valid experimental procedure with necessary equipment but does not provide a method to reduce experimental error, so the response earned 5 of the 6 available points. Part (b) earned 2 of 3 points for correctly applying Newton's second law but not deriving a correct final expression for the coefficient of static friction, because the fraction in the answer is the inverse of the correct expression. Parts (c) and (d) earned full credit.

Sample: P1 Q2 B
Score: 7

Part (a) describes a valid experimental procedure with necessary equipment but does not include measurement equipment or provide a method to reduce experimental error, so the response earned 4 of the 6 available points. No points were earned in part (b) because the friction force and normal force are not expressed in terms of measured quantities. Full credit was earned for parts (c) and (d).

Sample: P1 Q2 C
Score: 2

No points were earned in parts (a) and (b) because no viable experimental procedure is provided. Full credit was earned in part (c). No points were earned in part (d).