CollegeBoard

AP® Physics 1: Algebra-Based Practice Exam

From the 2016 Administration

NOTE: This is a modified version of the 2016 AP Physics 1: Algebra-Based Exam.

Contents

Note: This publication shows the page numbers that appeared in the ***2015–16 AP Exam Instructions*** book and in the actual exam. This publication was not repaginated to begin with page 1.

Exam Instructions

The following contains instructions taken from the *2015–16 AP Exam Instructions* book.

AP® Physics 1: Algebra-Based Exam

Regularly Scheduled Exam Date: Tuesday afternoon, May 3, 2016

Late-Testing Exam Date: Thursday afternoon, May 19, 2016

Section I Total Time: 1 hr. 30 min. Section II Total Time: 1 hr. 30 min.

AP® Physics 2: Algebra-Based Exam

Regularly Scheduled Exam Date: Wednesday afternoon, May 4, 2016

Late-Testing Exam Date: Friday morning, May 20, 2016

Section I Total Time: 1 hr. 30 min. Section II Total Time: 1 hr. 30 min.

Section I

Total Time: 1 hour 30 minutes
Calculator allowed
Number of Questions: 50*
Percent of Total Score: 50%
Writing Instrument: Pencil required

**The number of questions may vary slightly depending on the form of the exam.*

Section II

Total Time: 1 hour 30 minutes
Calculator allowed
Number of Questions Physics 1: 5
Number of Questions Physics 2: 4
Percent of Total Score: 50%
Writing Instrument: Pen with black or dark blue ink, or pencil

What Proctors Need to Bring to This Exam

- Exam packets
- Answer sheets
- AP Student Packs
- *2015-16 AP Coordinator's Manual*
- This book — *AP Exam Instructions*
- AP Exam Seating Chart template(s)
- School Code and Home-School/Self-Study Codes
- Extra calculators
- Extra rulers or straightedges
- Pencil sharpener
- Container for students' electronic devices (if needed)
- Extra No. 2 pencils with erasers
- Extra pens with black or dark blue ink
- Extra paper
- Stapler
- Watch
- Signs for the door to the testing room
  - "Exam in Progress"
  - "Cell phones are prohibited in the testing room"

Students are permitted to use rulers, straightedges, and four-function, scientific, or graphing calculators for these entire exams (Sections I and II). Before starting the exam administration, make sure each student has an appropriate calculator, and any student with a graphing calculator has a model from the approved list on page 47 of the *2015-16 AP Coordinator's Manual*. See pages 44–47 of the *AP Coordinator's Manual* for more information. If a student does not have an appropriate calculator or has a graphing calculator not on the approved list, you may provide one from your supply. If the student does not want to use the calculator you provide or does not want to use a calculator at all, he or she must hand copy, date, and sign the release statement on page 45 of the *AP Coordinator's Manual*.

Students may have no more than two calculators on their desks. Calculators may not be shared. Calculator memories do not need to be cleared before or after the exam. Students with Hewlett-Packard 48–50 Series and Casio FX-9860 graphing calculators may use cards designed for use with these calculators. Proctors should make sure infrared ports (Hewlett-Packard) are not facing each other. **Since graphing calculators can be used to store data, including text, proctors should monitor that students are using their calculators appropriately. Attempts by students to use the calculator to remove exam questions and/or answers from the room may result in the cancellation of AP Exam scores.**

Tables containing equations commonly used in physics are included in each AP Exam booklet, for use during the entire exam. Students are NOT allowed to bring their own copies of the equation tables to the Exam room.

SECTION I: Multiple Choice

! Do not begin the exam instructions below until you have completed the appropriate General Instructions for your group.

Make sure you begin the exam at the designated time. Remember, you must complete a seating chart for this exam. See pages 305–306 for a seating chart template and instructions. See the *2015-16 AP Coordinator's Manual* for exam seating requirements (pages 49–52).

Physics 1: Algebra-Based

If you are giving the regularly scheduled exam, say:

> **It is Tuesday afternoon, May 3, and you will be taking the AP Physics 1: Algebra-Based Exam.**

If you are giving the alternate exam for late testing, say:

> **It is Thursday afternoon, May 19, and you will be taking the AP Physics 1: Algebra-Based Exam.**

Physics 2: Algebra-Based

If you are giving the regularly scheduled exam, say:

> **It is Wednesday afternoon, May 4, and you will be taking the AP Physics 2: Algebra-Based Exam.**

If you are giving the alternate exam for late testing, say:

> **It is Friday morning, May 20, and you will be taking the AP Physics 2: Algebra-Based Exam.**

In a moment, you will open the packet that contains your exam materials. By opening this packet, you agree to all of the AP Program's policies and procedures outlined in the *2015-16 Bulletin for AP Students and Parents*. You may now remove the shrinkwrap from your exam packet and take out the Section I booklet, but do not open the booklet or the shrinkwrapped Section II materials. Put the white seals aside. . . .

Carefully remove the AP Exam label found near the top left of your exam booklet cover. Now place it on page 1 of your answer sheet on the light blue box near the top right-hand corner that reads "AP Exam Label."

If students accidentally place the exam label in the space for the number label or vice versa, advise them to leave the labels in place. They should not try to remove the label; their exam can still be processed correctly.

> **Read the statements on the front cover of Section I and look up when you have finished. . . .**
>
> **Sign your name and write today's date. Look up when you have finished. . . .**
>
> **Now print your full legal name where indicated. Are there any questions? . . .**
>
> **Turn to the back cover of your exam booklet and read it completely. Look up when you have finished. . . .**
>
> **Are there any questions? . . .**
>
> **You will now take the multiple-choice portion of the exam. You should have in front of you the multiple-choice booklet and your answer sheet. Open your answer sheet to page 2. You may never discuss these specific multiple-choice questions at any time in any form with anyone, including your teacher and other students. If you disclose these questions through any means, your AP Exam score will be canceled.**
>
> **You must complete the answer sheet using a No. 2 pencil only. Mark all of your responses on pages 2 and 3 of your answer sheet. Remember, for numbers 1 through 45 on answer sheet page 2, mark only the single best answer to each question. The answer sheet has circles marked A–E for each of these questions. For this exam, you will use only the circles marked A–D. For numbers 131 through 135 at the bottom of answer sheet page 3, mark the <u>two</u> best answer choices for each question. Completely fill in the circles. If you need to erase, do so carefully and completely. No credit will be given for anything written in the exam booklet. Scratch paper is not allowed, but you may use the margins or any blank space in the exam booklet for scratch work. Rulers, straightedges, and calculators may be used for the entire exam. You may place these items on your desk. Are there any questions? . . .**
>
> **You have 1 hour and 30 minutes for this section. Open your Section I booklet and begin.**

Note Start Time here __________. Note Stop Time here __________. Check that students are marking their answers in pencil on their answer sheets and that they are not looking at their shrinkwrapped Section II booklets. After 1 hour and 20 minutes, say:

> **There are 10 minutes remaining.**

After 10 minutes, say:

> **Stop working. Close your booklet and put your answer sheet on your desk, face up. Make sure you have your AP number label and an AP Exam label on page 1 of your answer sheet. Sit quietly while I collect your answer sheets.**

Collect an answer sheet from each student. Check that each answer sheet has an AP number label and an AP Exam label. After all answer sheets have been collected, say:

> **Now you must seal your exam booklet using the white seals you set aside earlier. Remove the white seals from the backing and press one on each area**

of your exam booklet cover marked "PLACE SEAL HERE." Fold each seal over the back cover. When you have finished, place the booklet on your desk, face up. I will now collect your Section I booklet. . . .

Collect a Section I booklet from each student. Check that each student has signed the front cover of the sealed Section I booklet.

There is a 10-minute break between Sections I and II. When all Section I materials have been collected and accounted for and you are ready for the break, say:

Please listen carefully to these instructions before we take a 10-minute break. Please put all of your calculators under your chair. Your calculators and all items you placed under your chair at the beginning of this exam must stay there, and you are not permitted to open or access them in any way. Leave your shrinkwrapped Section II packet on your desk during the break. You are not allowed to consult teachers, other students, notes, or textbooks during the break. You may not make phone calls, send text messages, check email, use a social networking site, or access any electronic or communication device. Remember, you may never discuss the multiple-choice questions at any time in any form with anyone, including your teacher and other students. If you disclose these questions through any means, your AP Exam score will be canceled. Are there any questions? . . .

You may begin your break. Testing will resume at ________.

SECTION II: Free Response

After the break, say:

May I have everyone's attention? Place your Student Pack on your desk. . . .

You may now remove the shrinkwrap from the Section II packet, but do not open the exam booklet until you are told to do so. . . .

Read the bulleted statements on the front cover of the exam booklet. Look up when you have finished. . . .

Now take an AP number label from your Student Pack and place it on the shaded box. If you don't have any AP number labels, write your AP number in the box. Look up when you have finished. . . .

Read the last statement. . . .

Using a pen with black or dark blue ink, print the first, middle, and last initials of your legal name in the boxes and print today's date where indicated. This constitutes your signature and your agreement to the statements on the front cover. . . .

Turn to the back cover and, using your pen, complete Item 1 under "Important Identification Information." Print the first two letters of your last name and the first letter of your first name in the boxes. Look up when you have finished. . . .

In Item 2, print your date of birth in the boxes. . . .

In Item 3, write the school code you printed on the front of your Student Pack in the boxes. . . .

Read Item 4. . . .

Are there any questions? . . .

I need to collect the Student Pack from anyone who will be taking another AP Exam. You may keep it only if you are not taking any other AP Exams this year. If you have no other AP Exams to take, place your Student Pack under your chair now. . . .

Read the information on the back cover of the exam booklet. Do not open the booklet until you are told to do so. Look up when you have finished. . . .

Collect the Student Packs. Then say:

Are there any questions? . . .

Rulers, straightedges, and calculators may be used for Section II. Be sure these items are on your desk. . . .

You have 1 hour and 30 minutes to complete Section II. You are responsible for pacing yourself, and you may proceed freely from one question to the next.

If you are giving the AP Physics 1: Algebra-Based Exam, say:

Section II has 5 questions. It is suggested that you spend approximately 25 minutes each for questions 2 and 3, and 13 minutes each for questions 1, 4, and 5.

If you are giving the AP Physics 2: Algebra-Based Exam, say:

Section II has 4 questions. It is suggested that you spend approximately 25 minutes each for questions 2 and 3, and 20 minutes each for questions 1 and 4.

You must write your answers in the exam booklet using a pen with black or dark blue ink or a No. 2 pencil. If you use a pencil, be sure that your writing is dark enough to be easily read. If you need more paper during the exam, raise your hand. At the top of each extra sheet of paper you use, be sure to write only your AP number and the question number you are working on. Do not write your name. Are there any questions? . . .

You may begin.

Note Start Time here __________. Note Stop Time here __________. You should also make sure that Hewlett-Packard calculators' infrared ports are not facing each other and that students are not sharing calculators. After 1 hour and 20 minutes, say:

There are 10 minutes remaining.

After 10 minutes, say:

Stop working and close your exam booklet. Place it on your desk, face up. . . .

If any students used extra paper for a question in the free-response section, have those students staple the extra sheet(s) to the first page corresponding to that question in their exam booklets. Complete an Incident Report. A single Incident Report may be completed for multiple students per exam subject per administration (regular or late testing) as long as all of the required information is provided. Include all exam booklets with extra sheets of paper in an Incident Report return envelope (see page 60 of the *2015-16 AP Coordinator's Manual* for complete details). Then say:

> **Remain in your seat, without talking, while the exam materials are collected. . . .**

Collect a Section II booklet from each student. Check for the following:

- Exam booklet front cover: The student placed an AP number label on the shaded box and printed his or her initials and today's date.
- Exam booklet back cover: The student completed the "Important Identification Information" area.

When all exam materials have been collected and accounted for, return to students any electronic devices you may have collected before the start of the exam.

If you are giving the regularly scheduled exam, say:

> **You may not discuss or share these specific free-response questions with anyone unless they are released on the College Board website in about two days. Your AP Exam score results will be available online in July.**

If you are giving the alternate exam for late testing, say:

> **None of the questions in this exam may ever be discussed or shared in any way at any time. Your AP Exam score results will be available online in July.**

If any students completed the AP number card at the beginning of this exam, say:

> **Please remember to take your AP number card with you. You will need the information on this card to view your scores and order AP score reporting services online.**

Then say:

> **You are now dismissed.**

All exam materials must be placed in secure storage until they are returned to the AP Program after your school's last administration. Before storing materials, check the "School Use Only" section on page 1 of the answer sheet and:

- Fill in the appropriate section number circle in order to access a separate AP Instructional Planning Report (for regularly scheduled exams only) or subject score roster at the class section or teacher level. See "Post-Exam Activities" in the *2015-16 AP Coordinator's Manual*.
- Check your list of students who are eligible for fee reductions and fill in the appropriate circle on their registration answer sheets.

Be sure to give the completed seating chart to the AP Coordinator. Schools must retain seating charts for at least six months (unless the state or district requires that they be retained for a longer period of time). Schools should not return any seating charts in their exam shipments unless they are required as part of an Incident Report.

Student Answer Sheet for the Multiple-Choice Section

Use this section to capture student responses. (Note that the following answer sheet is a sample, and may differ from one used in an actual exam.)

AP® Answer Sheet 2016

AP Number Label (from Student Pack)

B123456789T

AP Exam Label (from Section I Booklet)

CollegeBoard

COMPLETE THIS AREA AT EVERY EXAM.

USE NO. 2 PENCIL ONLY

To maintain the security of the exam and the validity of my AP score, I will allow no one else to see the multiple-choice questions. I will seal the multiple-choice booklet when asked to do so, and I will not discuss these questions with anyone at any time after completing the section. I am aware of and agree to the AP Program's policies and procedures as outlined in the *2015-16 Bulletin for AP Students and Parents*, including using testing accommodations (e.g., extended time, computer, etc.) only if I have been preapproved by College Board Services for Students with Disabilities.

A. SIGNATURE — Sign your legal name as it will appear on your college applications. — Date

B. LEGAL NAME — Omit apostrophes, Jr., II.

Legal Last Name — First 15 Letters | Legal First Name — First 12 Letters | MI

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z –

C. YOUR AP NUMBER

0 1 2 3 4 5 6 7 8 9

D. EXAM DATE

Month | Day

E. EXAM START TIME

AM: 6 7 8 9 10 11 | PM: 12 1 2 3 4 5

F. MULTIPLE-CHOICE BOOKLET SERIAL NUMBER

S

G. ONLINE PROVIDER CODE

H. AP EXAM I AM TAKING USING THIS ANSWER SHEET

Exam Name: | Form: | Form Code:

785208

SCHOOL USE ONLY

Section Number: 1 2 3 4 5 6 7 8 9

Fee Reduction Granted: 1 Option 1 2 Option 2

COMPLETE THIS AREA ONLY ONCE.

I. AREA CODE AND PHONE NUMBER

INTERNATIONAL PHONE

J. SCHOOL YOU ATTEND

SCHOOL CODE | School Name | City | State | Country

K. DATE OF BIRTH

Month: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec | Day | Year

L. SOCIAL SECURITY NUMBER (Optional)

M. COLLEGE TO RECEIVE YOUR AP SCORE REPORT

COLLEGE CODE — Using the college code listed in the AP Student Pack, indicate the **ONE** college that you want to receive your AP score report.

College Name | City | State | Country

N. CURRENT GRADE LEVEL

Not yet in 9th grade; 9th; 10th; 11th; 12th; No longer in high school

O. STUDENT SEARCH SERVICE®

Colleges and scholarship programs may request your information to inform you of educational opportunities and financial aid.

Would you like us to supply your information? Yes / No

If you don't answer and previously chose to participate in this service, we will continue providing your information.

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COMPLETE THIS AREA AT EACH EXAM (IF APPLICABLE).

P. SURVEY QUESTIONS — Answer the survey questions in the AP Student Pack. Do not put responses to exam questions in this section.

1 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	4 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	7 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ
2 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	5 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	8 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ
3 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	6 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	9 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ

Q. LANGUAGE — Do not complete this section unless instructed to do so.

If this answer sheet is for the French Language and Culture, German Language and Culture, Italian Language and Culture, Spanish Language and Culture, or Spanish Literature and Culture Exam, please answer the following questions. Your responses will not affect your score.

1. Have you lived or studied for one month or more in a country where the language of the exam you are now taking is spoken?

   ◯ Yes ◯ No

2. Do you regularly speak or hear the language at home?

   ◯ Yes ◯ No

QUESTIONS 1–75

Indicate your answers to the exam questions in this section (pages 2 and 3). Mark only one response per question for Questions 1 through 120. If a question has only four answer options, do not mark option E. Answers written in the multiple-choice booklet will not be scored.

COMPLETE MARK ● EXAMPLES OF INCOMPLETE MARKS

You must use a No. 2 pencil and marks must be complete. Do not use a mechanical pencil. It is very important that you fill in the entire circle darkly and completely. If you change your response, erase as completely as possible. Incomplete marks or erasures may affect your score.

1 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	26 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	51 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
2 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	27 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	52 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
3 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	28 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	53 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
4 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	29 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	54 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
5 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	30 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	55 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
6 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	31 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	56 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
7 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	32 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	57 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
8 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	33 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	58 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
9 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	34 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	59 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
10 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	35 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	60 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
11 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	36 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	61 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
12 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	37 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	62 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
13 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	38 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	63 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
14 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	39 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	64 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
15 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	40 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	65 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
16 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	41 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	66 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
17 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	42 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	67 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
18 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	43 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	68 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
19 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	44 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	69 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
20 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	45 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	70 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
21 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	46 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	71 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
22 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	47 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	72 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
23 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	48 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	73 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
24 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	49 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	74 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
25 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	50 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	75 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

ETS USE ONLY

Exam		⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
		⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
Exam		⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
		⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

SELECTED MEDIA EXAMS	R	W	O	OTHER EXAMS	R	W	O
PT02				TOTAL			
PT03				Subscore (if applicable)			
PT04				Subscore (if applicable)			

DO NOT WRITE IN THIS AREA

QUESTIONS 76–120

Be sure each mark is dark and completely fills the circle. If a question has only four answer options, do not mark option E.

76	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	91	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	106	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
77	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	92	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	107	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
78	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	93	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	108	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
79	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	94	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	109	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
80	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	95	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	110	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
81	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	96	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	111	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
82	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	97	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	112	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
83	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	98	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	113	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
84	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	99	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	114	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
85	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	100	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	115	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
86	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	101	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	116	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
87	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	102	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	117	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
88	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	103	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	118	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
89	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	104	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	119	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
90	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	105	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	120	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

QUESTIONS 121–126

For Students Taking AP Biology

Write your answer in the boxes at the top of the griddable area and fill in the corresponding circles. Mark only one circle in any column. You will receive credit only if the circles are filled in correctly.

121 | 122 | 123 | 124 | 125 | 126

		/	/	/	
–	.	.	.	.	.
		0	0	0	0
	1	1	1	1	1
	2	2	2	2	2
	3	3	3	3	3
	4	4	4	4	4
	5	5	5	5	5
	6	6	6	6	6
	7	7	7	7	7
	8	8	8	8	8
	9	9	9	9	9

QUESTIONS 131–142

For Students Taking AP Physics 1 or AP Physics 2

Mark two responses per question. You will receive credit only if both correct responses are selected.

131	Ⓐ Ⓑ Ⓒ Ⓓ	135	Ⓐ Ⓑ Ⓒ Ⓓ	139	Ⓐ Ⓑ Ⓒ Ⓓ
132	Ⓐ Ⓑ Ⓒ Ⓓ	136	Ⓐ Ⓑ Ⓒ Ⓓ	140	Ⓐ Ⓑ Ⓒ Ⓓ
133	Ⓐ Ⓑ Ⓒ Ⓓ	137	Ⓐ Ⓑ Ⓒ Ⓓ	141	Ⓐ Ⓑ Ⓒ Ⓓ
134	Ⓐ Ⓑ Ⓒ Ⓓ	138	Ⓐ Ⓑ Ⓒ Ⓓ	142	Ⓐ Ⓑ Ⓒ Ⓓ

DO NOT WRITE IN THIS AREA

COMPLETE THIS AREA ONLY ONCE.

R. YOUR MAILING ADDRESS

Use the address abbreviations from your AP Student Pack. Fill in only one circle per column. Indicate a space in your address by leaving a blank box; do not grid that column.

STREET ADDRESS (include street number, street name, apartment number, etc.)

CITY

STATE

AK, AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY, Puerto Rico, AA, AE, AP, Other

ZIP OR POSTAL CODE

COUNTRY CODE

S. FOR STUDENTS OUTSIDE THE UNITED STATES ONLY

If your address does not fit in the spaces provided in Item R, fill in as many circles as you can, then fill in the circle in Item S and print the remainder of your address in the spaces provided.

Address | City | State or Province | Country | ZIP or Postal Code

T. STUDENT IDENTIFIER (Student ID Number)

U. EMAIL ADDRESS

By providing your email address, you are granting the College Board permission to use your email in accordance with the policies in the *2015-16 Bulletin for AP Students and Parents.*

V. SEX

- Female
- Male

W. WHICH LANGUAGE DO YOU KNOW BEST?

- English
- English and another language about the same
- Another language

X. RACIAL/ETHNIC GROUP

Please answer both questions about Hispanic origin and about race. For the following questions about your identity, Hispanic origins are not races.

(You may mark all that apply.)

a. Are you of Hispanic, Latino, or Spanish origin?

- No, not of Hispanic, Latino, or Spanish origin
- Yes, Cuban
- Yes, Mexican
- Yes, Puerto Rican
- Yes, another Hispanic, Latino, or Spanish origin

b. What is your race?

- American Indian or Alaska Native
- Asian (including Indian subcontinent and Philippines origin)
- Black or African American (including Africa and Afro-Caribbean origin)
- Native Hawaiian or other Pacific Islander
- White (including Middle Eastern origin)

Y. PARENTAL EDUCATION LEVEL

In the first column, indicate the highest level of education of one parent/guardian, and indicate whether this is your mother/female guardian or father/male guardian. Then, if applicable, indicate the highest level of education of your other parent/guardian in the second column, and indicate whether this is your mother/female guardian or father/male guardian.

- **Mother or female guardian**
- **Father or male guardian**
- Grade school
- Some high school
- High school diploma or equivalent
- Vocational or trade school
- Some college
- Associate or two-year degree
- Bachelor's or four-year degree
- Some graduate or professional school
- Graduate or professional degree

Section I: Multiple-Choice Questions

This is the multiple-choice section of the 2016 AP exam.
It includes cover material and other administrative instructions
to help familiarize students with the mechanics of the exam.
(Note that future exams may differ in look from the following content.)

For purposes of test security and/or statistical analysis, some questions have been removed from the version of the exam that was administered in 2016. Therefore, the timing indicated here may not be appropriate for a practice exam.

AP® Physics 1: Algebra-Based Exam

SECTION I: Multiple Choice

2016

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

At a Glance

Total Time
1 hour, 30 minutes
Number of Questions
40
Percent of Total Score
50%
Writing Instrument
Pencil required
Electronic Device
Calculator allowed

Instructions

Section I of this exam contains 40 multiple-choice questions. Pages containing equations and other information are also printed in this booklet. Calculators, rulers, and straightedges may be used in this section.

Indicate all of your answers to the multiple-choice questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work.

Because this section offers only four answer options for each question, do not mark the (E) answer circle for any question. If you change an answer, be sure that the previous mark is erased completely.

For questions 1 through 36, select the single best answer choice for each question. After you have decided which of the choices is best, completely fill in the corresponding circle on the answer sheet. Here is a sample question and answer.

Sample Question	Sample Answer
Chicago is a (A) state (B) city (C) country (D) continent	Ⓐ ● Ⓒ Ⓓ Ⓔ

For questions 131 through 134, select the two best answer choices for each question. After you have decided which two choices are best, completely fill in the two corresponding circles on the answer sheet. Here is a sample question and answer.

Sample Question	Sample Answer
New York is a (A) state (B) city (C) country (D) continent	● ● Ⓒ Ⓓ

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all of the multiple-choice questions.

Your total score on Section I is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

Form I
Form Code 4MBP4-S

83

AP® PHYSICS 1 TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS	
Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	Coulomb's law constant, $k = 1/4\pi\varepsilon_0 = 9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant, $G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2$
Speed of light, $c = 3.00 \times 10^{8}$ m/s	Acceleration due to gravity at Earth's surface, $g = 9.8\ \text{m/s}^2$

UNIT SYMBOLS								
	meter,	m	kelvin,	K	watt,	W	degree Celsius,	°C
	kilogram,	kg	hertz,	Hz	coulomb,	C		
	second,	s	newton,	N	volt,	V		
	ampere,	A	joule,	J	ohm,	Ω		

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following conventions are used in this exam.

I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.
II. Assume air resistance is negligible unless otherwise stated.
III. In all situations, positive work is defined as work done <u>on</u> a system.
IV. The direction of current is conventional current: the direction in which positive charge would drift.
V. Assume all batteries and meters are ideal unless otherwise stated.

AP® PHYSICS 1 EQUATIONS

MECHANICS

$$v_x = v_{x0} + a_x t$$

$$x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$$

$$v_x^2 = v_{x0}^2 + 2a_x (x - x_0)$$

$$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$$

$$\left|\vec{F}_f\right| \le \mu \left|\vec{F}_n\right|$$

$$a_c = \frac{v^2}{r}$$

$$\vec{p} = m\vec{v}$$

$$\Delta\vec{p} = \vec{F}\,\Delta t$$

$$K = \frac{1}{2} m v^2$$

$$\Delta E = W = F_{\parallel} d = F d \cos\theta$$

$$P = \frac{\Delta E}{\Delta t}$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega = \omega_0 + \alpha t$$

$$x = A\cos(2\pi f t)$$

$$\vec{\alpha} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$$

$$\tau = r_\perp F = r F \sin\theta$$

$$L = I\omega$$

$$\Delta L = \tau\,\Delta t$$

$$K = \frac{1}{2} I \omega^2$$

$$\left|\vec{F}_s\right| = k\left|\vec{x}\right|$$

$$U_s = \frac{1}{2} k x^2$$

$$\rho = \frac{m}{V}$$

a = acceleration
A = amplitude
d = distance
E = energy
f = frequency
F = force
I = rotational inertia
K = kinetic energy
k = spring constant
L = angular momentum
ℓ = length
m = mass
P = power
p = momentum
r = radius or separation
T = period
t = time
U = potential energy
V = volume
v = speed
W = work done on a system
x = position
y = height
α = angular acceleration
μ = coefficient of friction
θ = angle
ρ = density
τ = torque
ω = angular speed

$$\Delta U_g = m g \Delta y$$

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$T_s = 2\pi\sqrt{\frac{m}{k}}$$

$$T_p = 2\pi\sqrt{\frac{\ell}{g}}$$

$$\left|\vec{F}_g\right| = G\frac{m_1 m_2}{r^2}$$

$$\vec{g} = \frac{\vec{F}_g}{m}$$

$$U_G = -\frac{G m_1 m_2}{r}$$

ELECTRICITY

$$\left|\vec{F}_E\right| = k\left|\frac{q_1 q_2}{r^2}\right|$$

$$I = \frac{\Delta q}{\Delta t}$$

$$R = \frac{\rho\ell}{A}$$

$$I = \frac{\Delta V}{R}$$

$$P = I\,\Delta V$$

$$R_s = \sum_i R_i$$

$$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$$

A = area
F = force
I = current
ℓ = length
P = power
q = charge
R = resistance
r = separation
t = time
V = electric potential
ρ = resistivity

WAVES

$$\lambda = \frac{v}{f}$$

f = frequency
v = speed
λ = wavelength

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

Triangle
$A = \frac{1}{2} bh$

Circle
$A = \pi r^2$
$C = 2\pi r$

Rectangular solid
$V = \ell w h$

Cylinder
$V = \pi r^2 \ell$
$S = 2\pi r \ell + 2\pi r^2$

Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

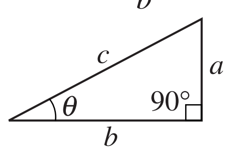
A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

Right triangle
$c^2 = a^2 + b^2$

$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$



PHYSICS 1

Section I
40 Questions
Time—90 minutes

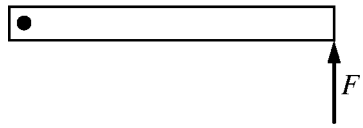
Note: To simplify calculations, you may use $g = 10\ \mathrm{m/s^2}$ in all problems.

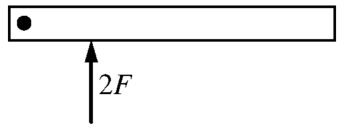
Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

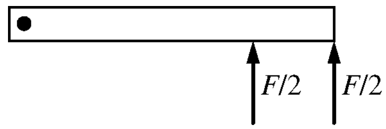
1. A kitten sits in a lightweight basket near the edge of a table. A person accidentally knocks the basket off the table. As the kitten and basket fall, the kitten rolls, turns, kicks, and catches the basket in its claws. The basket lands on the floor with the kitten safely inside. If air resistance is negligible, what is the acceleration of the kitten-basket system while the kitten and basket are in midair?

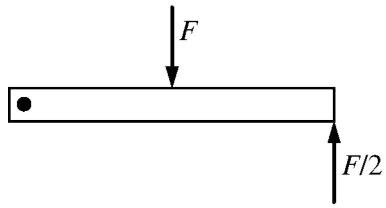
(A) The acceleration is directed downward with magnitude less than g because the basket is light.
(B) The acceleration is directed downward with magnitude equal to g because the system is a projectile.
(C) The acceleration fluctuates because of the rolling, turning, and kicking motion of the kitten.
(D) The acceleration cannot be determined without knowing how hard the basket is pushed.

2. A solid metal bar is at rest on a horizontal frictionless surface. It is free to rotate about a vertical axis at the left end. The figures below show forces of different magnitudes that are exerted on the bar at different locations. In which case does the bar's angular speed about the axis increase at the fastest rate?

(A)


(B)


(C)


(D)


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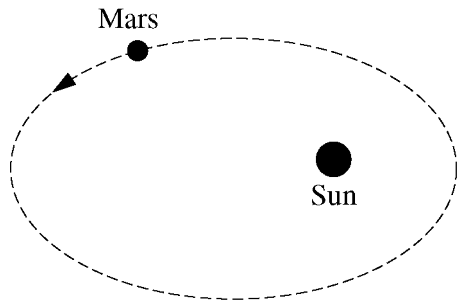
Speed	10 m/s	20 m/s	30 m/s
Braking Distance	6.1 m	23.9 m	53.5 m

3. To analyze the characteristics and performance of the brakes on a 1500 kg car, researchers collected the data shown in the table above. It shows the car's speed when the brakes are first applied and the corresponding braking distance required to stop the car. The magnitude of the average braking force on the car is most nearly

   (A) 75,000 N
   (B) 30,000 N
   (C) 12,000 N
   (D) 1600 N



Note: Figure not drawn to scale.

4. Mars moves in an elliptical orbit around the Sun, and the mass of Mars is much less than the mass of the Sun. At the instant shown above, Mars is getting farther away from the Sun. How does this affect the potential energy of the Mars-Sun system and the magnitude of Mars's angular momentum with respect to the Sun?

	System Potential Energy	Mars's Angular Momentum
(A)	Increases	Increases
(B)	Increases	Remains the same
(C)	Decreases	Decreases
(D)	Decreases	Remains the same

5. An ice-skater is moving at a constant velocity across an icy pond. The skater throws a snowball directly ahead. Which of the following correctly describes the velocity of the center of mass of the skater-snowball system immediately after the snowball is thrown? Assume friction and air resistance are negligible.

   (A) It is equal to the velocity of the snowball.
   (B) It is equal to the new velocity of the skater.
   (C) It is equal to half the original velocity of the skater.
   (D) It is equal to the original velocity of the skater.

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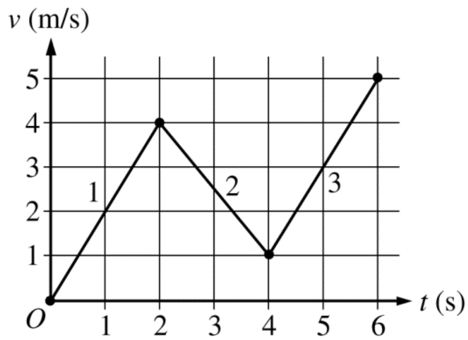
Questions 6-8 refer to the following material.



The graph above shows velocity v as a function of time t for a 0.50 kg object traveling along a straight line. The graph has three segments labeled 1, 2, and 3. A rope exerts a constant force of magnitude F_T on the object along its direction of motion the whole time. During segment 2 only, a frictional force of magnitude F_f is also exerted on the object.

6. Which of the following correctly ranks the displacement Δx for the three segments of the object's motion?

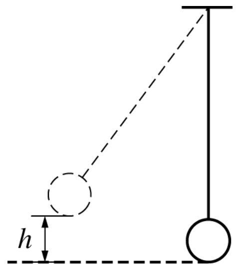
   (A) $\Delta x_3 > \Delta x_2 > \Delta x_1 > 0$
   (B) $\Delta x_1 = \Delta x_2 = \Delta x_3 > 0$
   (C) $(\Delta x_1 = \Delta x_3) > \Delta x_2 > 0$
   (D) $(\Delta x_1 = \Delta x_3) > 0 > \Delta x_2$

7. Which of the following expressions correctly relates the magnitudes F_f and F_T?

   (A) $F_f < F_T$
   (B) $F_f = F_T$
   (C) $F_T < F_f < 2F_T$
   (D) $F_f = 2F_T$

8. For another identical object initially at rest, no frictional force is exerted during segment 2 (between $t = 2$ s and $t = 4$ s). A rope exerts the same constant force of magnitude F_T as in the previous scenario. What is the change in the object's kinetic energy during segment 2?

   (A) 3.75 J
   (B) 4.00 J
   (C) 12.0 J
   (D) 16.0 J



9. The pendulum shown in the figure above reaches a maximum height h above the equilibrium position as it oscillates. Assuming friction and air resistance are negligible, which of the following is true about the total energy of the Earth-pendulum system as the pendulum oscillates?

   (A) It is at a maximum when the pendulum is at its lowest position.
   (B) It is at a maximum when the pendulum is at its maximum height h.
   (C) It is constant throughout the pendulum's motion.
   (D) It is at a minimum when the pendulum is somewhere between its lowest and highest positions.

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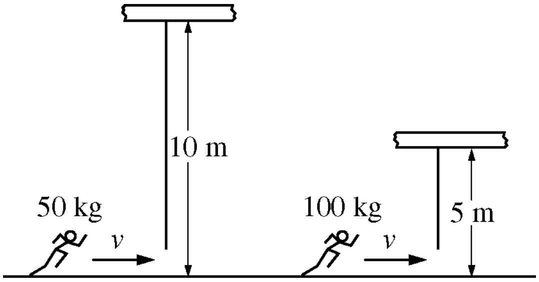
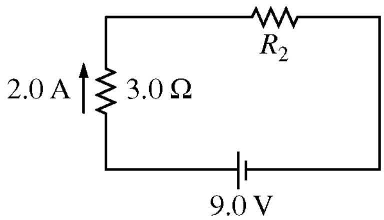


10. A 50 kg athlete running at speed v grabs a light rope that hangs from a 10-meter-high platform and swings to a maximum of 1.8 m above the ground. Later, a 100 kg athlete, running at the same speed, grabs a similar rope hanging from a 5-meter-high platform. What is the maximum height to which the 100 kg athlete swings?

(A) 0.9 m
(B) 1.8 m
(C) 2.5 m
(D) 3.6 m



11. A 9.0 V battery and two resistors are connected in the circuit shown above. The current through the $3.0\ \Omega$ resistor is 2.0 A. What is the potential difference across resistor R_2?

(A) 9.0 V
(B) 6.0 V
(C) 3.0 V
(D) 1.5 V

12. A student is asked to determine the work done on a block of wood when the block is pulled horizontally using an attached string. The student is supplied with a spring scale, a stopwatch, and a meterstick. Which of the following graphical analysis techniques will allow the student to determine the work done on the block by the string?

(A) Graphing the force as a function of time and calculating the slope
(B) Graphing the force as a function of time and calculating the area under the curve
(C) Graphing the force as a function of distance and calculating the slope
(D) Graphing the force as a function of distance and calculating the area under the curve

13. Block A and block B move toward each other on a level frictionless track. Block A has mass m and velocity $+v$. Block B has mass $2m$ and velocity $-v$. The blocks collide, and during the collision the magnitude of the net force exerted on block A is F. What is the magnitude of the net force exerted on block B, and why does it have that value?

(A) $2F$, because the mass of block B is twice that of block A and the blocks have the same acceleration during the collision.
(B) $F/2$, because the mass of block B is twice that of block A and the blocks have the same acceleration during the collision.
(C) F, because the blocks have the same speed immediately before the collision.
(D) F, because the net force is equal to the mutual contact force between the blocks.

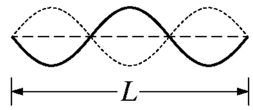
14. The data in the table below were recorded during an experiment in which two carts on a frictionless one-dimensional track collide head-on. What are the values of the magnitude of the change in momentum Δp_2 of cart 2 and the magnitude of its average acceleration a_2 during the collision?

	Cart 1	Cart 2
Mass	5 kg	1 kg
Average Force	15 N	15 N
Change in Momentum	$0.3\ \text{kg•m/s}$	Δp_2
Average Acceleration	$3\ \text{m/s}^2$	a_2

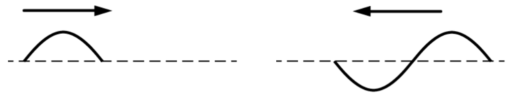
	$\underline{\Delta p_2}$	$\underline{a_2}$
(A)	$0.3\ \text{kg•m/s}$	$3\ \text{m/s}^2$
(B)	$0.3\ \text{kg•m/s}$	$15\ \text{m/s}^2$
(C)	$1.5\ \text{kg•m/s}$	$3\ \text{m/s}^2$
(D)	$1.5\ \text{kg•m/s}$	$15\ \text{m/s}^2$

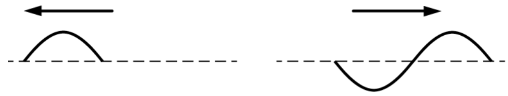
15. A 1.0 kg lump of clay is sliding to the right on a frictionless surface with speed $2\ \text{m/s}$. It collides head-on and sticks to a 0.5 kg metal sphere that is sliding to the left with speed $4\ \text{m/s}$. What is the kinetic energy of the combined objects after the collision?

(A) 6 J
(B) 4 J
(C) 2 J
(D) 0 J



16. A guitar string of length L can vibrate with three antinodes, as shown above. The straight dashed line shows the equilibrium position of the string. The wave pattern is most likely formed by the superposition of which of the following pulses or waves?

(A) 

(B) 

(C) Two periodic waves of wavelength $L/3$, one moving to the left and one moving to the right

(D) Two periodic waves of wavelength $2L/3$, one moving to the left and one moving to the right

17. A speaker is at rest at the side of a straight road. The speaker produces a steady sound of constant frequency. A student is standing still near the speaker. Two vehicles are driven down the road: a truck approaching the speaker and a car moving away from the speaker. If the sound is represented by wave fronts, the student and the vehicle drivers each observe a different amount of time between successive wave fronts: t_s for the student, t_t for the truck driver, and t_c for the car driver. Which of the following correctly ranks the times?

(A) $t_s < t_t < t_c$
(B) $t_c < t_s < t_t$
(C) $t_t < t_s < t_c$
(D) $t_t < t_c < t_s$

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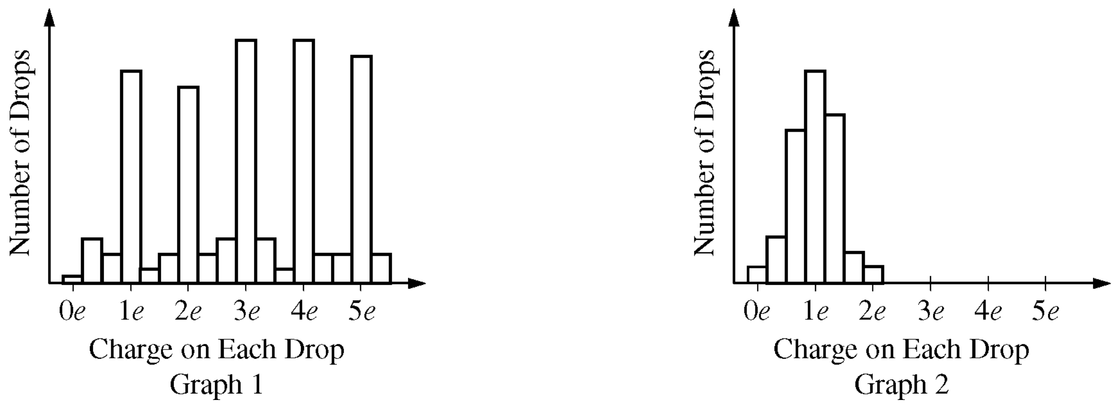


18. Tiny drops of oil that have different amounts of electric charge produced by a random process are sprayed into a region between a positively and a negatively charged plate. The charge on each drop is determined by analyzing the effect of the electric force on the drop's motion. Two graphs of the number of drops as a function of the charge on each drop, where e is the charge of an electron, are shown above. Which graph shows the most likely result after repeating the experiment many times, and why?

(A) Graph 1, because it shows peaks with approximately the same amplitude
(B) Graph 1, because it shows that within experimental error charge only exists in multiples of e
(C) Graph 2, because it shows a peak value at the charge of an electron
(D) Graph 2, because it shows a narrower range of measurement error

GO ON TO THE NEXT PAGE.

19. The magnitude of the gravitational field on the surface of a particular planet is $2g$. The planet's mass is half the mass of Earth. What is the planet's radius in terms of the radius R_E of Earth?

(A) $R_E/4$

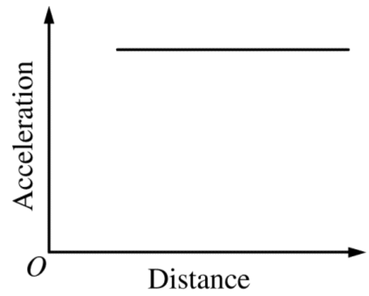
(B) $R_E/2$

(C) $R_E/\sqrt{2}$

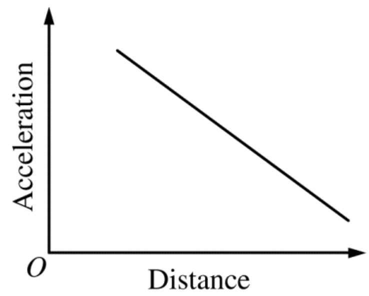
(D) $2R_E$

20. A small object with positive charge Q is fixed in place. A small bead with positive charge q is released from rest from the position shown above. In the absence of forces other than the electric force, which of the following graphs best represents the bead's acceleration as a function of its distance from the fixed object?

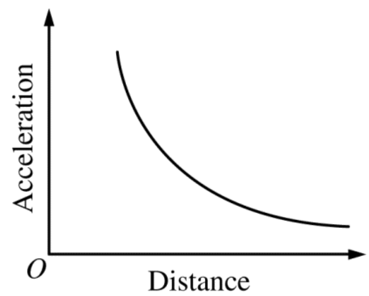
(A)



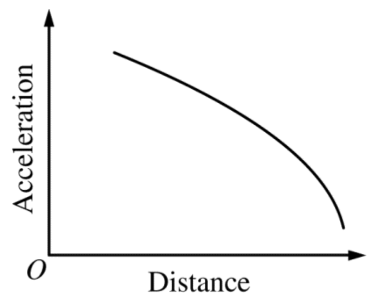
(B)



(C)



(D)



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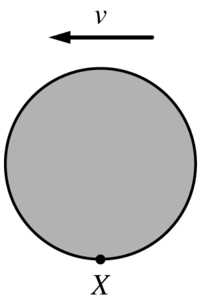
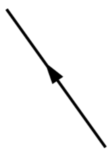
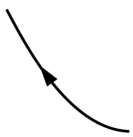


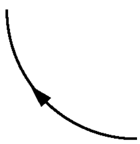
Top View

21. A stone disk is sliding on frictionless ice to the west with speed v, as shown in the figure above. 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?

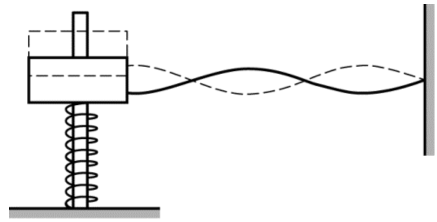
(A)  A northward linear path

(B)  A northwestward linear path

(C)  A parabolic path

(D)  A circular path

Questions 22-23 refer to the following material.



The figure above shows a pole with a spring around it and a 0.10 kg block with a hole in the middle on top of the spring. A light horizontal string is attached to the block and a wall. When the block is oscillating at 5.0 Hz, the standing wave shown is formed.

22. The spring constant of the spring is approximately which of the following?

(A) 100 N/m
(B) 10 N/m
(C) 1.0 N/m
(D) 0.1 N/m

23. What additional measurement is needed to determine the speed of the wave on the string?

(A) The mass of the string
(B) The effective spring constant of the spring
(C) The distance between the wall and the block
(D) The amplitude of the block's oscillation

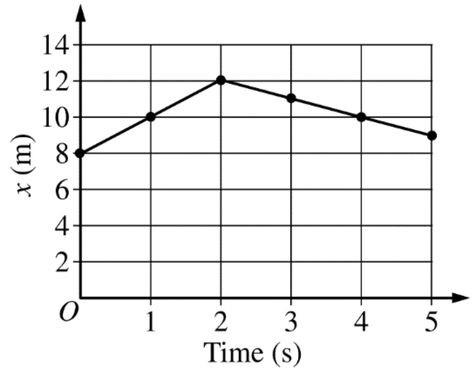
24. Two identical blocks with mass 5.0 kg each are connected to the opposite ends of a compressed spring. The blocks initially slide together on a frictionless surface with velocity $2\ \text{m/s}$ to the right. The spring is then released by remote control. At some later instant, the left block is moving at $1\ \text{m/s}$ to the left, and the other block is moving to the right. What is the speed of the center of mass of the system at that instant?

(A) $4\ \text{m/s}$

(B) $3\ \text{m/s}$

(C) $2\ \text{m/s}$

(D) $0\ \text{m/s}$



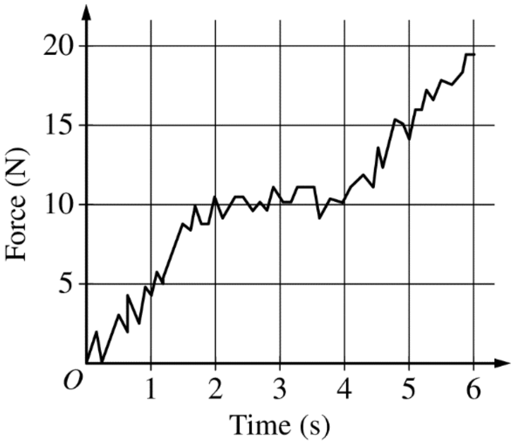
25. The graph above shows the position x as a function of time for the center of mass of a system of particles of total mass $6.0\ \text{kg}$. For a very short time interval around $2.0\ \text{s}$, an external force is exerted on an object in the system. What is the resulting change in momentum of the system?

(A) $52\ \text{kg}\bullet\text{m/s}$

(B) $6\ \text{kg}\bullet\text{m/s}$

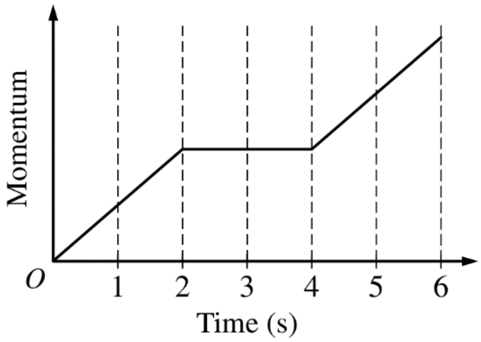
(C) $-6\ \text{kg}\bullet\text{m/s}$

(D) $-18\ \text{kg}\bullet\text{m/s}$

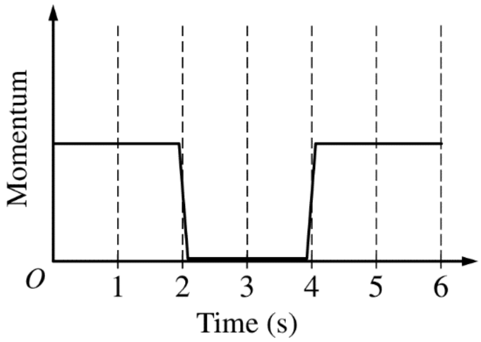


26. Using a force probe, a student generates the graph above of the force exerted on a small wagon as a function of time. The wagon starts from rest and rolls with negligible friction in the axles. Which of the following graphs best represents the wagon's momentum as a function of time?

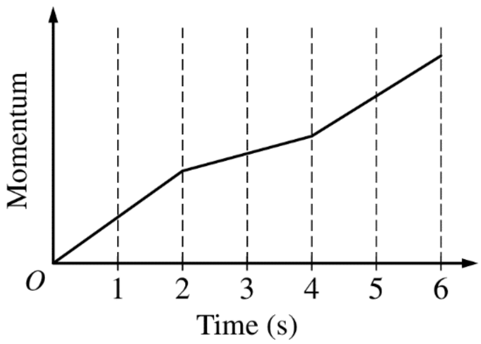
(A)



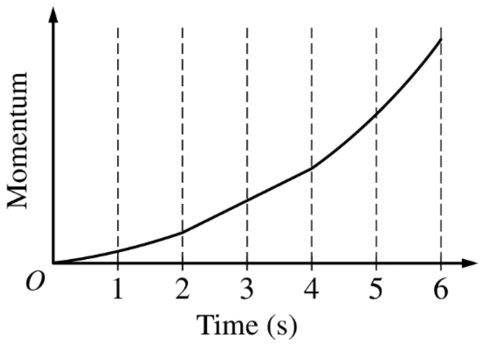
(B)



(C)



(D)



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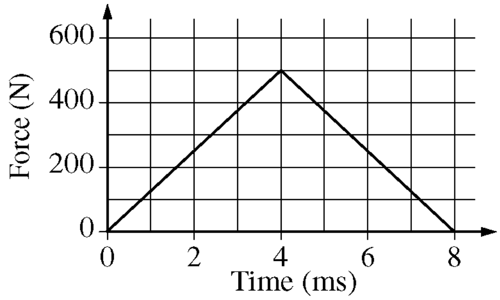


27. A 0.050 kg tennis ball is moving to the left at 10 m/s when it is hit by a tennis racket that is moving to the right. The magnitude of the force exerted on the ball by the racket as a function of time is shown in the figure above. What is the speed of the ball after the collision with the racket?

(A) 30 m/s

(B) 50 m/s

(C) 70 m/s

(D) 90 m/s

Figure *W*

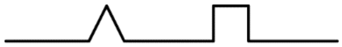


Figure *X*

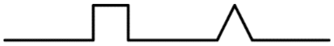


Figure *Y*

Figure *Z*

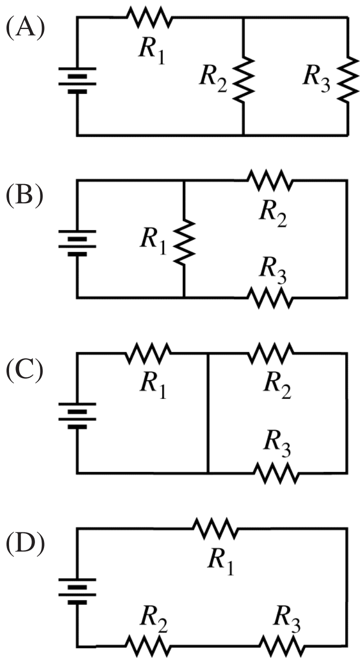
28. Two wave pulses are created simultaneously at opposite ends of a string and move toward the center of the string, as shown in the top figure above. Both pulses have the same width. The labeled figures show possible shapes of the string at different moments in time. Which of the following indicates a correct time order for the shape of the string as the pulses move along the string, come together, and move apart?

(A) Figure *X*, Figure *W*, Figure *X*
(B) Figure *X*, Figure *W*, Figure *Y*
(C) Figure *X*, Figure *Z*, Figure *X*
(D) Figure *X*, Figure *Z*, Figure *Y*

GO ON TO THE NEXT PAGE.

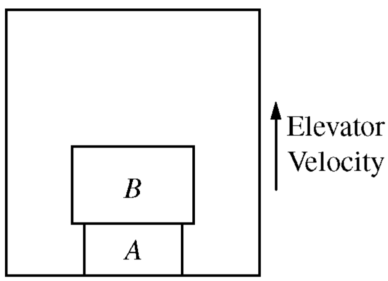
Circuit Element	Potential Difference (V)	Current (A)
Battery	10	8
Resistor R_1	6	8
Resistor R_2	4	3
Resistor R_3	4	5

29. The above table shows the potential difference and current for each circuit element in a circuit consisting of a battery and three resistors. Which of the following diagrams could represent the circuit?



30. An object starts from rest and slides with negligible friction down an air track tipped at an angle θ from the horizontal. A student records values of the object's position along the track at various times. The value of θ can best be determined from which of the following?

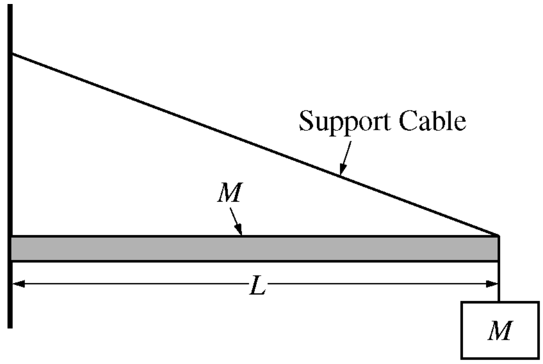
(A) The y-intercept of a graph of position as a function of time
(B) The y-intercept of a graph of position as a function of the square of time
(C) The slope of a graph of position as a function of time
(D) The slope of a graph of position as a function of the square of time



31. Box A of mass m sits on the floor of an elevator, with box B of mass $2m$ on top of it, as shown in the figure above. The elevator is moving upward and slowing down. F_A is the magnitude of the force exerted on box A by box B, F_B is the magnitude of the force exerted on box B by box A, and F_g is the magnitude of the gravitational force exerted on box B. Which of the following ranks the forces in order of increasing magnitude?

(A) $F_B = F_A = F_g$
(B) $(F_B = F_A) < F_g$
(C) $F_B < (F_A = F_g)$
(D) $F_g < F_B < F_A$

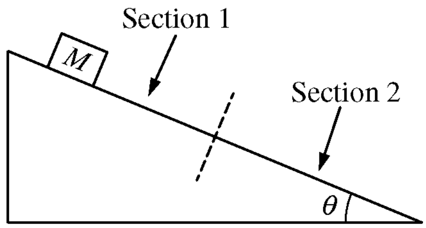
GO ON TO THE NEXT PAGE.



32. The figure above shows a uniform beam of length L and mass M that hangs horizontally and is attached to a vertical wall. A block of mass M is suspended from the far end of the beam by a cable. A support cable runs from the wall to the outer edge of the beam. Both cables are of negligible mass. The wall exerts a force F_W on the left end of the beam. For which of the following actions is the magnitude of the vertical component of F_W smallest?

(A) Keeping the support cable and block as shown in the diagram
(B) Moving the lower end of the support cable to the center of the beam and leaving the block at the outer end of the beam
(C) Keeping the lower end of the support cable at the outer end of the beam and moving the block to the center of the beam
(D) Moving both the support cable and the block to the center of the beam

Questions 33-34 refer to the following material.



The inclined plane in the figure above has two sections of equal length and different roughness. The dashed line shows where section 1 ends and section 2 begins. A block of mass M is placed at different locations on the incline. The coefficients of kinetic and static friction between the block and each section are shown in the table below.

Coefficient of Friction	Section 1	Section 2
Static	μ_{S1}	$\mu_{S2} (> \mu_{S1})$
Kinetic	μ_k	$2\mu_k$

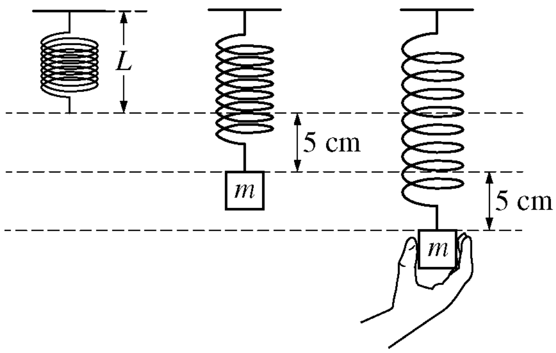
33. If the block is at rest on section 1 of the incline, what is the magnitude of the force of static friction exerted on the block by the incline?

(A) $\mu_{S1} Mg \cos\theta$
(B) $\mu_{S1} Mg \tan\theta$
(C) $Mg \sin\theta$
(D) $Mg/\tan\theta$

34. If the block is sliding up section 2, what is the magnitude of the force of friction that is exerted on the block by the incline?

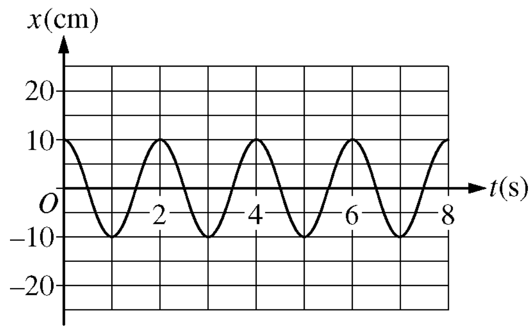
(A) $2\mu_k Mg \cos\theta$
(B) $2\mu_k Mg \tan\theta$
(C) $Mg \sin\theta$
(D) $Mg/\tan\theta$

GO ON TO THE NEXT PAGE.

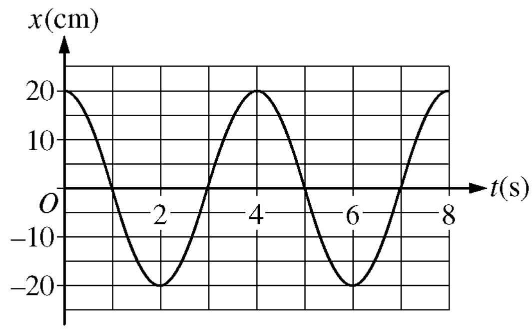


35. An object with mass m is suspended at rest from a spring with a spring constant of $200\ \text{N/m}$. The length of the spring is 5.0 cm longer than its unstretched length L, as shown above. A person then exerts a force on the object and stretches the spring an additional 5.0 cm. What is the total energy stored in the spring at the new stretched length?

(A) 0.25 J
(B) 1.0 J
(C) 10 J
(D) 20 J



Block A

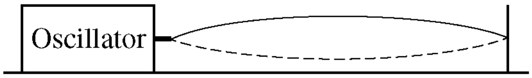


Block B

36. Two blocks are connected to identical ideal springs and are oscillating on a horizontal frictionless surface. Block A has mass m, and its motion is represented by the graph of position as a function of time shown above on the left. Block B's motion is represented above on the right. Which of the following statements comparing block B to block A is correct?

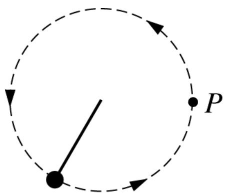
(A) Because block B covers more distance per cycle than block A, block B takes more time to complete each cycle.
(B) Because the spring attached to block B is initially stretched a greater distance, the spring constant is smaller and therefore block B has a slower average speed than block A does.
(C) Because block B has more mass, it has a slower average speed than block A does.
(D) Because block B has more mass, its acceleration is smaller than that of block A at any given displacement from the equilibrium position.

Directions: For each of the questions or incomplete statements below, two of the suggested answers will be correct. For each of these questions, you must select both correct choices to earn credit. No partial credit will be earned if only one correct choice is selected. Select the two that are best in each case and then fill in the corresponding circles that begin with number 131 on page 3 of the answer sheet.



131. The figure above shows a string held taut between a post and an oscillator that vibrates the end of the string. In an experiment, the oscillator is adjusted to find many frequencies that will create a standing wave, one of which is shown. The number of nodes in each standing wave is counted. Which of the following quantities must also be measured to determine the speed of traveling waves on the string? Select two answers.

(A) The length of the string
(B) The mass of the string
(C) The amplitudes of the standing wave patterns
(D) The frequencies of the standing wave patterns



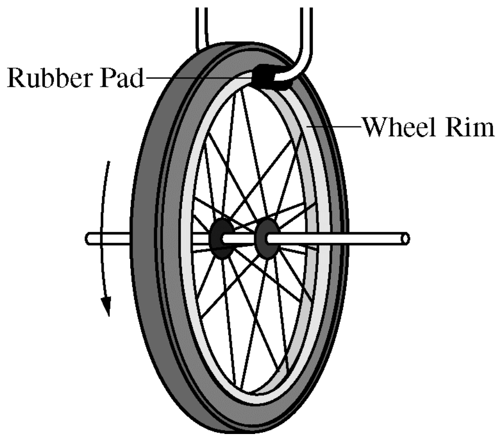
Side View

132. A ball attached to a light string swings in a counterclockwise vertical circle, as shown above. Which of the following arrows represent one of the forces exerted on the ball at the moment it passes through point P ? Select two answers.

(A) $\uparrow$
(B) $\rightarrow$
(C) $\downarrow$
(D) $\leftarrow$

133. Object A has mass 2 kg and is traveling to the right at speed $3\ \text{m/s}$. Object B is traveling to the left at $3\ \text{m/s}$. The objects collide head-on, and afterward each has a speed of $3\ \text{m/s}$. Which of the following could be the mass of object B ? Select two answers.

(A) 3 kg
(B) 2 kg
(C) 1 kg
(D) Negligible compared to 2 kg



134. Some bicycle brakes work by pressing rubber pads against the rim of the wheel. To test newly designed brakes, bicycle engineers mount a wheel of known rotational inertia on a low-friction axle, as shown above. The engineers spin the wheel with known initial angular speed and then apply the brakes with a constant force. Which of the following procedures would enable the engineers to find the torque exerted by the brakes on the wheel? Select two answers.

(A) Measuring how much time the wheel takes to come to rest
(B) Measuring how many rotations the wheel completes while coming to rest
(C) Measuring the distance from axle to brakes and the normal force between the rubber pads and the rim
(D) Measuring the mechanical energy dissipated as the rim rubs against the rubber pads

GO ON TO THE NEXT PAGE.

END OF SECTION I

IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON THIS SECTION.

DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

MAKE SURE YOU HAVE DONE THE FOLLOWING.

- **PLACED YOUR AP NUMBER LABEL ON YOUR ANSWER SHEET**
- **WRITTEN AND GRIDDED YOUR AP NUMBER CORRECTLY ON YOUR ANSWER SHEET**
- **TAKEN THE AP EXAM LABEL FROM THE FRONT OF THIS BOOKLET AND PLACED IT ON YOUR ANSWER SHEET.**

Section II: Free-Response Questions

This is the free-response section of the 2016 AP exam.
It includes cover material and other administrative instructions
to help familiarize students with the mechanics of the exam.
(Note that future exams may differ in look from the following content.)

AP® Physics 1: Algebra-Based Exam

SECTION II: Free Response

2016

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

At a Glance

Total Time
1 hour, 30 minutes
Number of Questions
5
Percent of Total Score
50%
Writing Instrument
Either pencil or pen with black or dark blue ink
Electronic Device
Calculator allowed
Suggested Time
Approximately 25 minutes each for questions 2 and 3 and 13 minutes each for questions 1, 4, and 5
Weight
Approximate weights:
Questions 2 and 3: 26% each
Questions 1, 4 and 5: 16% each

IMPORTANT Identification Information

PLEASE PRINT WITH PEN:

1. First two letters of your last name

   First letter of your first name

2. Date of birth

   Month Day Year

3. Six-digit school code

4. Unless I check the box below, I grant the College Board the unlimited right to use, reproduce, and publish my free-response materials, both written and oral, for educational research and instructional purposes. My name and the name of my school will not be used in any way in connection with my free-response materials. I understand that I am free to mark "No" with no effect on my score or its reporting.

   No, I do not grant the College Board these rights.

Instructions

The questions for Section II are printed in this booklet. You may use any blank space in the booklet for scratch work, but you must write your answers in the spaces provided for each answer. A table of information and lists of equations that may be helpful are in the booklet. Calculators, rulers, and straightedges may be used in this section.

All final numerical answers should include appropriate units. Credit for your work depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should show your work for each part in the space provided after that part. If you need more space, be sure to clearly indicate where you continue your work. Credit will be awarded only for work that is clearly designated as the solution to a specific part of a question. Credit also depends on the quality of your solutions and explanations, so you should show your work.

Write clearly and legibly. Cross out any errors you make; erased or crossed-out work will not be scored. You may lose credit for incorrect work that is not crossed out.

Manage your time carefully. You may proceed freely from one question to the next. You may review your responses if you finish before the end of the exam is announced.

Form I
Form Code 4MBP4-S

AP® PHYSICS 1 TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS	
Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	Coulomb's law constant, $k = 1/4\pi\varepsilon_0 = 9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant, $G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2$
Speed of light, $c = 3.00 \times 10^{8}$ m/s	Acceleration due to gravity at Earth's surface, $g = 9.8\ \text{m/s}^2$

UNIT SYMBOLS								
	meter,	m	kelvin,	K	watt,	W	degree Celsius,	°C
	kilogram,	kg	hertz,	Hz	coulomb,	C		
	second,	s	newton,	N	volt,	V		
	ampere,	A	joule,	J	ohm,	Ω		

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following conventions are used in this exam.

I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.
II. Assume air resistance is negligible unless otherwise stated.
III. In all situations, positive work is defined as work done <u>on</u> a system.
IV. The direction of current is conventional current: the direction in which positive charge would drift.
V. Assume all batteries and meters are ideal unless otherwise stated.

AP® PHYSICS 1 EQUATIONS

MECHANICS

$$v_x = v_{x0} + a_x t$$

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$$

$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$$

$$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$$

$$\left|\vec{F}_f\right| \le \mu\left|\vec{F}_n\right|$$

$$a_c = \frac{v^2}{r}$$

$$\vec{p} = m\vec{v}$$

$$\Delta\vec{p} = \vec{F}\,\Delta t$$

$$K = \frac{1}{2}mv^2$$

$$\Delta E = W = F_{\parallel}d = Fd\cos\theta$$

$$P = \frac{\Delta E}{\Delta t}$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega = \omega_0 + \alpha t$$

$$x = A\cos(2\pi f t)$$

$$\vec{\alpha} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$$

$$\tau = r_{\perp}F = rF\sin\theta$$

$$L = I\omega$$

$$\Delta L = \tau\,\Delta t$$

$$K = \frac{1}{2}I\omega^2$$

$$\left|\vec{F}_s\right| = k\left|\vec{x}\right|$$

$$U_s = \frac{1}{2}kx^2$$

$$\rho = \frac{m}{V}$$

a = acceleration
A = amplitude
d = distance
E = energy
f = frequency
F = force
I = rotational inertia
K = kinetic energy
k = spring constant
L = angular momentum
ℓ = length
m = mass
P = power
p = momentum
r = radius or separation
T = period
t = time
U = potential energy
V = volume
v = speed
W = work done on a system
x = position
y = height
α = angular acceleration
μ = coefficient of friction
θ = angle
ρ = density
τ = torque
ω = angular speed

$$\Delta U_g = mg\,\Delta y$$

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$T_s = 2\pi\sqrt{\frac{m}{k}}$$

$$T_p = 2\pi\sqrt{\frac{\ell}{g}}$$

$$\left|\vec{F}_g\right| = G\frac{m_1 m_2}{r^2}$$

$$\vec{g} = \frac{\vec{F}_g}{m}$$

$$U_G = -\frac{Gm_1 m_2}{r}$$

ELECTRICITY

$$\left|\vec{F}_E\right| = k\left|\frac{q_1 q_2}{r^2}\right|$$

$$I = \frac{\Delta q}{\Delta t}$$

$$R = \frac{\rho\ell}{A}$$

$$I = \frac{\Delta V}{R}$$

$$P = I\,\Delta V$$

$$R_s = \sum_i R_i$$

$$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$$

A = area
F = force
I = current
ℓ = length
P = power
q = charge
R = resistance
r = separation
t = time
V = electric potential
ρ = resistivity

WAVES

$$\lambda = \frac{v}{f}$$

f = frequency
v = speed
λ = wavelength

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

Triangle
$A = \frac{1}{2}bh$

Circle
$A = \pi r^2$
$C = 2\pi r$

Rectangular solid
$V = \ell wh$

Cylinder
$V = \pi r^2\ell$
$S = 2\pi r\ell + 2\pi r^2$

Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

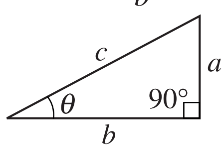
A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

Right triangle
$c^2 = a^2 + b^2$

$\sin\theta = \frac{a}{c}$

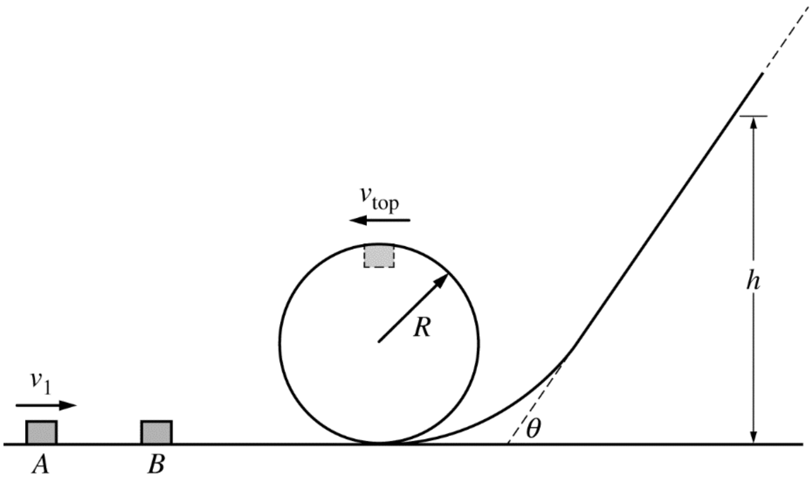
$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$



PHYSICS 1
Section II
5 Questions
Time—90 minutes

Directions: Questions 1, 4 and 5 are short free-response questions that require about 13 minutes each to answer and are worth 7 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



Note: Figure not drawn to scale.

1. (7 points, suggested time 13 minutes)

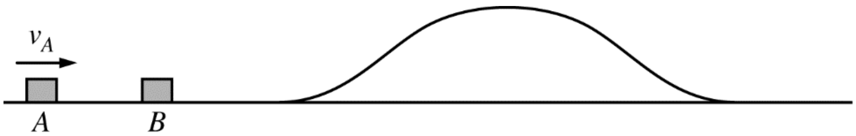
Two blocks A and B of equal mass m are on a frictionless track, as shown in the figure above. Block A, initially moving with speed v_1, has a perfectly elastic collision with block B. Block B has a speed v_1 immediately after the collision, and then it travels around a circular loop of radius R, where R is much larger than the size of the blocks. The speed of block B at the top of the loop is v_{top}. Block B then slides up a ramp until it comes momentarily to rest at a height h above the floor.

(a) Derive an equation for the height h in terms of m, R, v_{top}, and g, as appropriate.

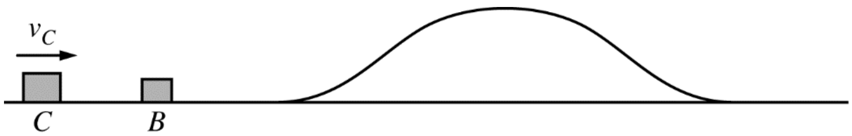
(b) Suppose that the speed v_1 of block A is doubled. Will the final height of block B be greater than, less than, or equal to $2h$?

____ Greater than $2h$ ____ Less than $2h$ ____ Equal to $2h$

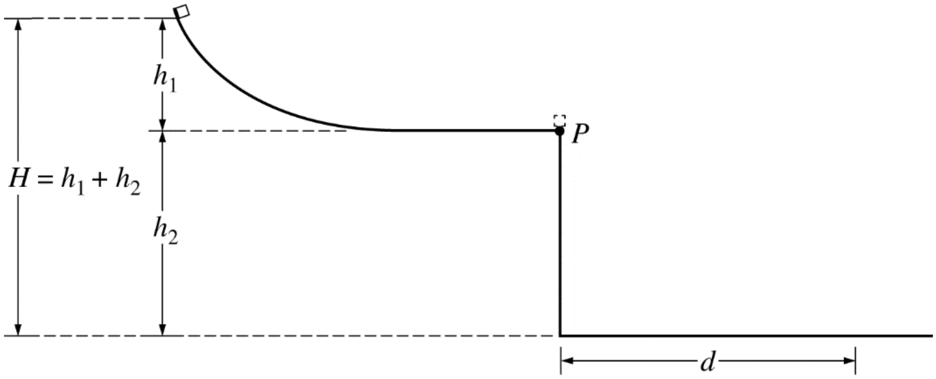
Briefly explain how you arrived at your answer.



(c) Blocks A and B (both of mass m) are moved to a different frictionless track, as shown above. Let v_A be the minimum initial speed for block A that allows block B to make it over the hump in the track. Block A is then replaced with a larger block, block C, which has mass $2m$, as shown below.



Block C makes a completely inelastic collision with block B so that both blocks stick together and travel along the track. What is the minimum initial speed v_C that block C must have so that the two-block system makes it over the hump? Express your answer in terms of v_A .



2. (12 points, suggested time 25 minutes)

A student releases a block of mass m from rest at the top of a slide of height h_1. The block moves down the slide and off the end of a table of height h_2, landing on the floor a horizontal distance d from the edge of the table. Friction and air resistance are negligible. The overall height H of the setup is determined by the height of the room. Therefore, if h_1 is increased, h_2 must decrease by the same amount so that the sum $h_1 + h_2$ remains equal to H. The student wants to adjust h_1 and h_2 to make d as large as possible.

(a)

i. Without using equations, explain why making h_1 very small would cause d to be small, even though h_2 would be large.

ii. Without using equations, explain why making h_2 very small would cause d to be small, even though h_1 would be large.

(b) Derive an equation for d in terms of h_1, h_2, m, and physical constants, as appropriate.

(c)

i. Write the equation or step in your derivation in part (b) (not your final answer) that supports your reasoning in part (a)i.

Briefly explain your choice.

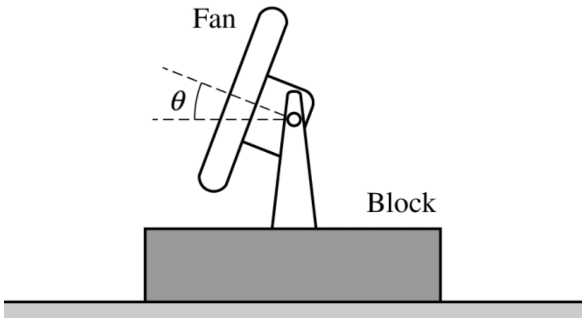
ii. Write the equation or step in your derivation in part (b) (not your final answer) that supports your reasoning in part (a)ii.

Briefly explain your choice.

(d) If the experiment is repeated on the Moon without changing h_1 or h_2, will the new landing distance d be greater than, less than, or the same as the landing distance when the experiment is performed on Earth?

____ Greater than ____ Less than ____ The same as

Briefly explain how you arrived at your answer.



3. (12 points, suggested time 25 minutes)

A student in a physics lab has a block with a fan attached to it, as shown in the figure above. The fan has a pivot so that the angle θ it makes with the horizontal can be adjusted between $0°$ and $90°$. When the fan is pointed horizontally so that $\theta = 0°$, the block accelerates from rest along a track, even though there is friction between the block and the track. For the following questions, assume that the student has access to equipment that would usually be found in a school physics laboratory.

(a) Describe an experimental procedure that the student could use to measure the force F that the air exerts on the fan-block system when the fan is turned on. Assume that the magnitude of this force is the same for all angles θ .

i. What quantities would be measured?

ii. What equipment would be used for the measurements, and how would that equipment be used? Include a labeled diagram of the experimental setup.

iii. Describe the overall procedure to be used. Give enough detail so that another student could replicate the experiment.

iv. Describe how the force can be determined from the measurements described in parts (a)i–iii.

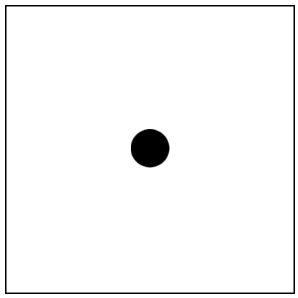
(b) Describe an experimental procedure that would allow the student to use the fan-block system, with the fan turned on, to find the coefficient of kinetic friction between the block and the track.

i. What quantities would be measured?

ii. What equipment would be used for the measurements, and how would that equipment be used? Include a labeled diagram of the experimental setup.

iii. Describe the overall procedure to be used. Give enough detail so that another student could replicate the experiment.

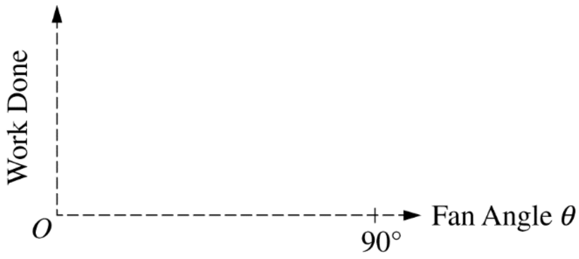
iv. On the dot to the right, which represents the fan-block system, draw and label the forces (not components) that are exerted on the system during the experiment described in parts (b)i–iii. Represent each force by a distinct arrow starting on, and pointing away from, the dot.



(c) Describe how to analyze the data from the experiment described in parts (b)i–iii in order to determine the coefficient of kinetic friction between the block and the track. Your analysis may include the force F exerted by the air on the fan-block system. Do not add to the free-body diagram in part (b)iv.

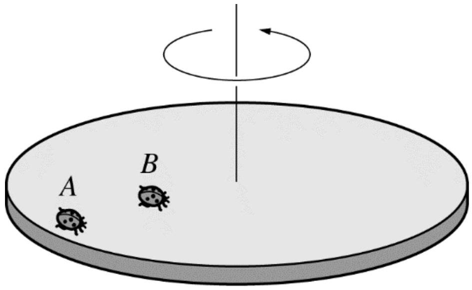
Question 3 continues on next page.

(d) In a different experiment, the student attaches the block to the top of a low-friction cart. On the axes below, sketch a graph of the work done by air on the fan-block-cart system as a function of θ when the system travels a fixed distance D.



THIS PAGE MAY BE USED FOR SCRATCH WORK.

GO ON TO THE NEXT PAGE.



4. (7 points, suggested time 13 minutes)

Two ladybugs are standing on a rotating disk that is spinning counterclockwise, as shown in the figure above. Assume that friction in the bearings of the axle is negligible.

(a)

i. Is the angular speed of ladybug *A* greater than, less than, or the same as the angular speed of ladybug *B* ?

____ Greater ____ Less ____ The same

Briefly justify your answer.

ii. Is the linear speed of ladybug *A* greater than, less than, or the same as the linear speed of ladybug *B* ?

____ Greater ____ Less ____ The same

Briefly justify your answer.

(b) Ladybug A begins walking in a circular path in the direction of the disk's rotation. Does the magnitude of the angular momentum of the disk alone (not the ladybugs-disk system) increase, decrease, or stay the same?

____ Increase ____ Decrease ____ Stay the same

Briefly explain your reasoning.

(c) In a different scenario, a single ladybug is standing near the edge of the disk at a distance of $0.9R$ from the center, where R is the radius of the disk, as shown in Figure 1 below. The rotational inertia of the ladybug-disk system is I_1, and the disk completes one rotation in 2.5 s. The ladybug then walks toward the center of the disk to a distance of $0.1R$ from the center and comes to a stop relative to the disk, as shown in Figure 2. Now the rotational inertia of the system is I_2, and the disk completes one rotation every 2.0 s.

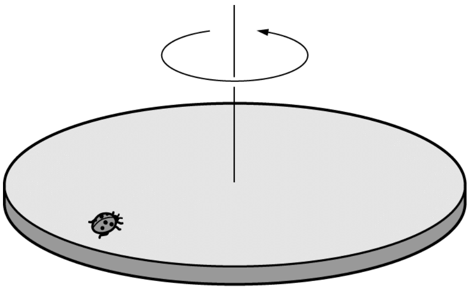


Figure 1

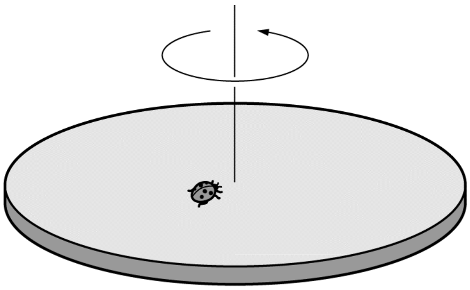


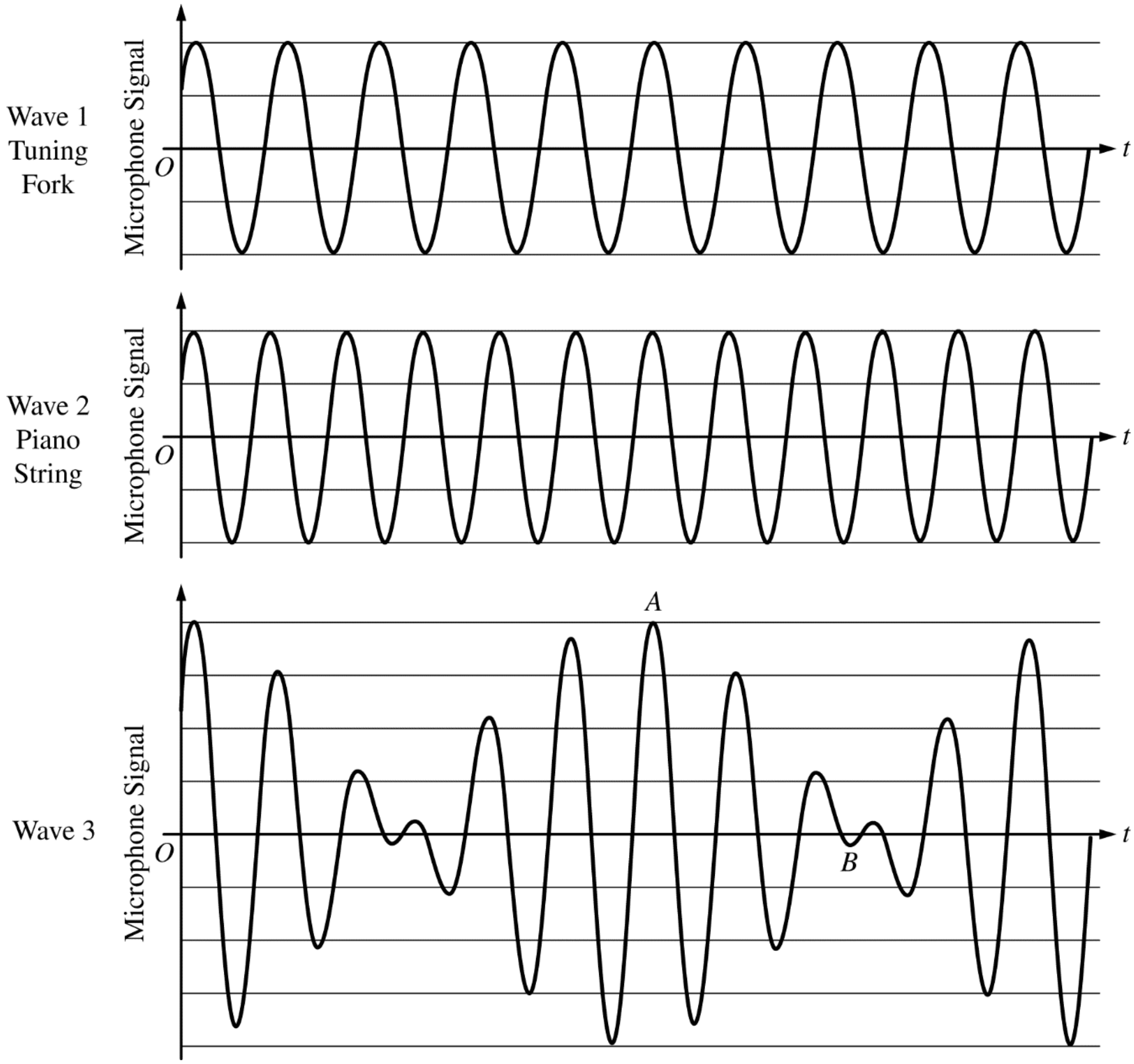
Figure 2

i. Derive an equation for I_2 in terms of I_1.

ii. While the ladybug is walking toward the center of the disk, does it exert a torque on the disk?

____ Yes ____ No

Briefly explain your reasoning.



5. (7 points, suggested time 13 minutes)

The graphs shown above represent the variations in air pressure in the sound waves recorded by a microphone as functions of time t. Wave 1 represents the sound wave when a tuning fork has been struck, wave 2 represents the sound wave when a particular piano string has been struck, and wave 3 represents the sound wave when both the tuning fork and the piano string have been struck.

(a) Briefly explain why the peaks in wave 3 at time A and nearby times are relatively large.

(b) Briefly explain why the peaks in wave 3 at time *B* and nearby times are relatively small.

If the fundamental frequency of the piano string is close to the frequency of the tuning fork, the phenomenon illustrated in wave 3 is detectable by ear. A piano tuner can loosen or tighten a piano string to change the fundamental frequency of the string.

(c) In a clear, coherent paragraph-length response referring to the graphs on the previous page, describe how and why the graph of wave 3, including the locations of points *A* and *B*, would change as the piano tuner loosens or tightens the string. Your response should also describe how the sound heard by the piano tuner changes during the process of adjusting the frequency of the string and how the piano tuner can tell when the string's frequency matches that of the tuning fork.

THIS PAGE MAY BE USED FOR SCRATCH WORK.

STOP

END OF EXAM

**IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON THIS SECTION.**

THE FOLLOWING INSTRUCTIONS APPLY TO THE COVERS OF THE SECTION II BOOKLET.

- **MAKE SURE YOU HAVE COMPLETED THE IDENTIFICATION INFORMATION AS REQUESTED ON THE FRONT AND BACK COVERS OF THE SECTION II BOOKLET.**
- **CHECK TO SEE THAT YOUR AP NUMBER LABEL APPEARS IN THE BOX ON THE FRONT COVER.**
- **MAKE SURE YOU HAVE USED THE SAME SET OF AP NUMBER LABELS ON ALL AP EXAMS YOU HAVE TAKEN THIS YEAR.**

Multiple-Choice Answer Key

The following contains the answers to
the multiple-choice questions in this exam.

Answer Key for AP Physics 1 Practice Exam, Section I

Question 1: B	Question 21: C
Question 2: A	Question 22: A
Question 3: C	Question 23: C
Question 4: B	Question 24: C
Question 5: D	Question 25: D
Question 6: A	Question 26: D
Question 7: C	Question 27: A
Question 8: C	Question 28: B
Question 9: C	Question 29: A
Question 10: B	Question 30: D
Question 11: C	Question 31: B
Question 12: D	Question 32: D
Question 13: D	Question 33: C
Question 14: B	Question 34: A
Question 15: D	Question 35: B
Question 16: D	Question 36: D
Question 17: C	Question 131: A, D
Question 18: B	Question 132: C, D
Question 19: B	Question 133: B, D
Question 20: C	Question 134: A, B

Free-Response Scoring Guidelines

The following contains the scoring guidelines for the free-response questions in this exam.

Question 1

7 points total | **Distribution of points**

(a) 3 points

For using an equation expressing the conservation of energy — 1 point

$$mgh = 2mgR + \frac{1}{2}mv_{\text{top}}^2 \text{ or } mgh = (1/2)mv_1^2 \text{ or } mgh = (1/2)mv^2$$

For using two forms of energy when block B is at the top of the loop or using the initial kinetic energy — 1 point

For expressing the correct answer in terms of the listed quantities — 1 point

$$h = \frac{2mgR + \frac{1}{2}mv_{\text{top}}^2}{mg}$$

$$h = 2R + \frac{v_{\text{top}}^2}{2g}$$

(b) 2 points

For a correct answer "Greater than $2h$" with an explanation — 1 point

No point is earned for a correct selection without an explanation.

If an incorrect answer is selected, the following point for using conservation of energy can still be earned.

For using an equation or semi-quantitative reasoning expressing the conservation of energy Note: "semi-quantitative reasoning" here includes reasoning in terms of proportionality, squared relationships, etc. — 1 point

$$mgh = \frac{1}{2}mv_1^2$$

$$h = \frac{v_1^2}{2g}$$

Question 1 (continued)

	Distribution of points
(c) 2 points	
Correct answer: $v_C = \frac{3}{2} v_A$	
Note: there is no "answer point", so no credit is awarded for an answer with no work shown	
For using momentum conservation to relate the speeds before and after the completely inelastic collision between blocks B and C	1 point
$2mv_C = (2m + m)v_{BC} = 3mv_{BC}$, where v_{BC} is the speed of blocks B and C after the collision	
$2v_C = 3v_{BC}$	
For setting the speed of blocks B and C after the collision equal to the speed of block B after its elastic collision with block A, in order for blocks B and C to make it over the hump.	1 point
$2v_C = 3v_A$	
$v_C = \frac{3}{2} v_A$	

Question 2

12 points total **Distribution of points**

(a)

i. 2 points

For recognizing a small horizontal velocity for the block at point P — 1 point

For stating or implying that the block doesn't go very far even though there is a longer fall time — 1 point

Example: Even though the large h_2 allows the block to stay in the air for a long time, the small h_1 means the system loses little gravitational potential energy and hence gains little kinetic energy so that it leaves the table with too little speed to cover much distance while aloft.

ii. 2 points

For recognizing a large horizontal velocity for the block at point P — 1 point

For mentioning a short time of flight for the falling block — 1 point

Example: Now the block gains a lot of kinetic energy on the ramp so that it leaves the table with a large horizontal speed. But the small h_2 means the block spends so little time in the air that it lands before covering much horizontal distance.

(b) 3 points

For using an energy conservation statement (corresponds to step 1 in example below) — 1 point

For setting up a time of flight calculation using vertical acceleration (corresponds to step 2a in example below) — 1 point

Note: derivation of t must be shown to earn credit.

For using $vt = d$ to determine distance traveled (corresponds to step 2b in example below) — 1 point

Example:

Step 1: Use energy conservation to find the block's speed at the bottom of ramp, which equals the launch speed v_1 at point P.

$$mgh_1 = \frac{1}{2}mv_1^2 \Rightarrow v_1 = \sqrt{2gh_1}$$

Step 2a: Find the time of flight, using the independence of the horizontal and vertical motion. Since the block leaves the table with zero *vertical* speed, the vertical kinematic equation $y = y_0 + v_{y0}t + \frac{1}{2}a_y t^2$ reduces to $h_2 = \frac{1}{2}gt^2$ (taking downward as positive). Solve for time to get $t = \sqrt{\frac{2h_2}{g}}$.

Step 2b. Find the horizontal distance d covered while in the air after point P. Since there are no horizontal forces exerted on the block, its horizontal velocity stays constant at v_1. So, the block travels a horizontal distance

$$d = v_1 t = \sqrt{2gh_1}\sqrt{\frac{2h_2}{g}} = 2\sqrt{h_1 h_2}$$

Question 2 (continued)

Distribution of points

(c)

i. 2 points

For mentioning a correct equation or step of reasoning (energy conservation on ramp)	1 point
For correctly explaining why this equation or step mirrors the reasoning of (a)i	1 point

Example: My energy conservation reasoning (part (b) step 1) mirrors my reasoning that a small ramp height corresponds to a low potential energy (mgh_1), which is converted into low kinetic energy and hence a low speed.

ii. 2 points

For mentioning a correct equation or step of reasoning (time of flight)	1 point
For correctly explaining why that equation or step mirrors the reasoning of (a)ii	1 point

Example: My time-of-flight calculation (part (b) step 2a) shows that t is proportional to $\sqrt{h_2}$, so a smaller falling distance h_2 corresponds to a smaller flight time.

(d) 1 point

Correct answer: "The same as"
Note: explanation is scored regardless of checkbox.
Point can be earned if response is consistent with answer in part (b)

For reasoning that is consistent with the functional dependence of the part (b) answer	1 point

Example:
As found in part (b), the distance d does not depend on g. So, doing the experiment on the Moon instead of Earth makes no difference. The increased time of flight (since weaker gravity makes the block take longer to land) compensates for the small speed gained by the block on the ramp.
Checked "Greater than" then g must be in the denominator in the incorrect equation in part (b)
Checked "Less than" then g must be in the numerator in the incorrect equation in part (b)

Question 3

12 points total | **Distribution of points**

(a)

i, ii, and iii) 2 points

Note: Parts i, ii, and iii are read together

For measuring the mass or weight of the relevant system — 1 point

For making a measurement of force (or something from which a force can be calculated) with the fan turned on — 1 point

Note: fan angles of either $0°$ or $90°$ need not be measured directly, since these are given as the minimum and maximum angles possible. If the procedure involves intermediate angles, then these angles must be measured.

Example 1 (variant - Example 1a in parentheses):

(a)i The downward force exerted by the fan-block system (or "mass", as read on a balance, of the system)

(a)ii A spring scale (or mechanical balance)

(a)iii Set the fan angle to $90°$. With the fan off, hang the system from a spring scale to find its weight (or place the system on a mechanical balance to find its mass). Turn the fan on, and record the force from the spring scale (or the mass reading from the mechanical balance).

Example 2:

(a)i Mass of the fan-block system and low-friction cart. Velocity of the cart as a function of time.

(a)ii Scale to measure mass. Motion detector to measure velocity as a function of time.

(a)iii Place the system and a low-friction cart on a scale to find the total mass of the fan-block and cart. Next, on a horizontal surface, place the fan-block on the cart, set the fan angle to zero, turn on the fan, and release the cart from rest. Use the motion detector to graph the cart velocity as a function of time.

iv) 1 point

For correctly indicating a method to determine the force exerted by air on the fan, using the measurements and procedure from parts (a) i, ii, and iii — 1 point

Example 1 (and 1a), continued from above:

Take the difference in the force readings with the fan off and the fan on. (1a: Multiply the difference in the mass readings by g). This difference is the force exerted by air on the fan.

Example 2, continued from above:

Estimate the average slope of the graph, which is the acceleration. Multiply acceleration by the total mass to find the force exerted by air on the fan.

Question 3 (continued)

Distribution of points

(b)

i, ii, and iii) 2 points

Note: Parts i, ii, and iii are read together
Note: In parts (b) i, ii, and iii, it is acceptable to say "the same as in part (a), with the following changes:", with changes to the procedure in part (a) then listed.

For describing measurements that would allow determination of the acceleration — 1 point
For describing a procedure that is practical/feasible in a school laboratory — 1 point

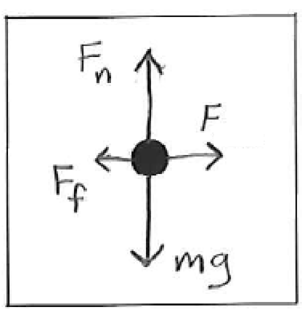
Example 3:
Place the fan-block on the track, with angle = 0. Place a motion detector behind it, set to graph velocity vs. time. Turn fan on, and release from rest. Repeat the procedure several times.

Example 4:
Place the fan-block on the track, with angle = 0. Place a photogate just in front of the block, and the second photogate a meter or two in front of the block. Measure distance from front of block to the front of that second photogate. Turn on fan and release the block from rest. The photogates measure the time it takes the block to travel the measured distance to the second photogate.

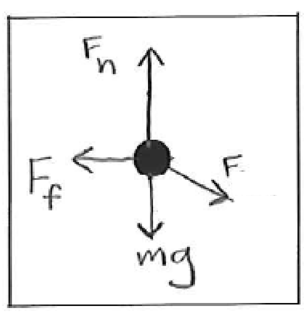
Example 5:
(b)i Angle of the fan. Velocity of fan-block system as a function of time.
(b)ii Protractor to measure the angle.
Motion detector to measure the velocity and time.
(b)iii Adjust the fan angle until the fan-block slides with a constant speed after being given a push. Use the motion detector to determine whether the speed is constant (zero slope on a graph of velocity as a function of time).

iv) 1 point

For correctly drawn and labeled vectors for the force exerted by air on fan and for the frictional force exerted on the block by the track, corresponding to the experiment described in part (b)iii. Other forces correctly drawn and labeled AND no incorrect forces, corresponding to the experiment described in part (b)iii. — 1 point



Examples 3 & 4



Example 5

Question 3 (continued)

Distribution of points

(c) 4 points

For using kinematic data to obtain acceleration, a, or showing that $a = 0$ — 1 point

Alternatively the point can be earned using the Work-Energy solution with kinetic energy $K = (1/2)mv^2$

For relating frictional force and coefficient of kinetic friction as $F_f = \mu_K F_N$ — 1 point

For a correct representation of the normal force, correctly referring back to a measurement of the fan-block system — 1 point

$F_N = mg$ if $\theta = 0$ or $F_N = mg + F\sin\theta$ if $\theta \neq 0$

For using Newton's second law, consistently with normal force above, for the appropriate forces or force components in the direction of the fan's motion that would lead to the determination of the coefficient of kinetic friction — 1 point

$F_{\text{net}} = ma$

$F - F_f = ma$

$$\mu_k = \frac{F - ma}{mg} \text{ if } \theta = 0 \text{ or } \mu_k = \frac{F\cos\theta - ma}{mg + F\sin\theta} \text{ if } \theta \neq 0$$

Alternatively the point can be earned using the Work-Energy solution that would lead to the determination of the coefficient of kinetic friction.

Example 3 (continued from above): $\theta = 0$ Determine the slope of each v vs. t graph, to get the acceleration for each trial, and average the accelerations. Call this average acceleration a. The kinetic frictional force exerted by track on block is $F_f = \mu F_n = \mu mg$, where m is the mass of the fan-block as found in part (a), since the acceleration is purely horizontal and hence F_n and mg must balance. So, by Newton's second law, letting F denote the force exerted by the air on the fan found in part (a), we get

$F_{\text{net}} = ma$

$F - F_f = ma$

$F - \mu mg = ma$

Solve for μ to get $\mu = \dfrac{F - ma}{mg}$

Example 4 (continued from above): $\theta = 0$ Let d denote distance from block to second photogate and t denote the corresponding time. Since $v_0 = 0$, $d = \frac{1}{2}at^2$ and hence $a = \dfrac{2d}{t^2}$. For each trial, calculate that acceleration, and take the average, which becomes our best estimate of a. [Rest of solution is as in example 3]

Distribution of points

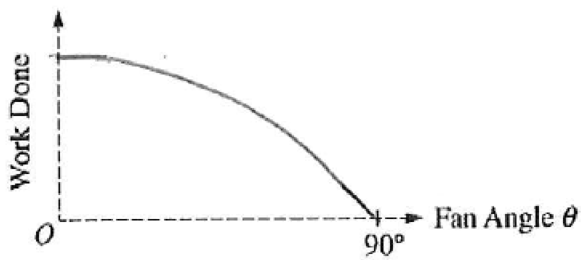
Example 5 (continued from above): $\theta = 0$ Since the acceleration is zero, the net horizontal force is zero. From Newton's second law,

$$F_f = \mu mg = F\cos\theta$$

Solving for μ_k:

$$\mu_k = \frac{F\cos\theta - ma}{mg + F\sin\theta} \text{ if } \theta \neq 0$$

(d) 2 points



A correct graph shows the work done as proportional to $\cos\theta$.

For showing a curve that continually decreases from a maximum value at 0° to a minimum value of zero at 90°	1 point
For showing a curve that is concave-downward (i.e. that has a negative second derivative)	1 point

Question 4

7 points total | **Distribution of points**

(a)

i. 1 point

Correct answer: "The same"
For selecting "The same" and explaining that both ladybugs have the same angular displacement over the same interval of time, or that all points on the disk rotate at the same rate — 1 point

Notes: No credit is earned if the wrong answer is selected.
No credit is earned for a correct selection with a wrong explanation or no explanation given.

ii. 1 point

Correct answer: "Greater"
For selecting "Greater" and explaining that linear speed is proportional to (or increases with) distance from the center ($v = \omega R$) — 1 point

Notes: No credit is earned if the wrong answer is selected.
No credit is earned for a correct selection with a wrong explanation or no explanation given.

(b) 2 points

Correct answer: "Decrease"
If the wrong answer is selected, at most one point can be earned for the explanation.
For stating or implying that the system angular momentum does not change — 1 point
For stating that the ladybug gained angular momentum, the disk lost angular momentum — 1 point
Note: Full credit can be earned for an alternate solution involving the force exerted by the ladybug (while accelerating) causing a torque on the disk.

(c)

i. 2 points

For using an equation expressing the conservation of angular momentum with I and ω — 1 point

$I_2\omega_2 = I_1\omega_1$

For correctly substituting the angular speed values and obtaining a correct answer or an algebraic equivalent of the correct answer — 1 point

$$I_2 = \frac{I_1\omega_1}{\omega_2} = \frac{I_1(1/2.5)}{(1/2)}$$

$$I_2 = \frac{4}{5}I_1$$

Question 4 (continued)

Distribution of points

ii. 1 point

Correct answer: "Yes"

For selecting "Yes" and for providing evidence that a torque is exerted on the disk (e.g., the disk's angular momentum/speed changes, or the ladybug exerts a non-radial force on the disk) — 1 point

Notes: No credit is earned if the wrong answer is selected.
No credit is earned for a correct selection with a wrong explanation or no explanation given.

Question 5

7 points total | **Distribution of points**

(a) 1 point

For an explanation using superposition — 1 point

Note: The term “constructive interference”, while not a part of this course, is an acceptable explanation.

Example:

At A, a crest from wave 1 overlaps a crest from wave 2, and their superposition therefore results in a higher crest, as big as it can get for these two waves.

(b) 1 point

For an explanation using superposition — 1 point

Note: The term “destructive interference”, while not a part of this course, is an acceptable explanation.

Example:

At B, a crest from wave 1 overlaps an equally deep trough from wave 2, and hence the waves “cancel out” resulting in a small amplitude.

(c) 5 points

For mentioning that waves 1 and 2 become more similar (or, frequency/period of wave 2 decreases/increases), as points A and B (loud and soft sounds) in the graph of wave 3 get further apart — 1 point

For explaining why A and B (loud and soft sounds) get further apart in the graph of wave 3 — 1 point

Examples:

...because there are more wave peaks that constructively interfere before they start to destructively interfere.

or

... because the time interval between when the peaks coincide increases.

or

... because it takes more time for the peaks to get out of alignment.

For mentioning that A and B (loud and soft sounds) getting further apart corresponds to a longer time interval between the piano tuner hearing loud and soft sounds OR the piano tuner hears a lower beat frequency — 1 point

For mentioning that, when the string frequency matches that of the fork, the time interval between the loud and soft sounds is infinite OR the loudness no longer fluctuates OR there are no more beats heard by the tuner — 1 point

For a response that has sufficient paragraph structure, as described in the published requirements for the paragraph length response — 1 point

Example:

The piano tuner hears alternating loud to soft to loud corresponding to A to B to the next A on wave 3. This alternating pattern is called “beats.” As the frequency of the sound produced by the string (wave 2) becomes closer and closer to the tuning fork frequency (wave 1), the distance on the wave 3 graph between A and B (and the next A) becomes greater. That distance on the graph is really the time between beats, i.e., the beat period. So, as the string frequency approaches the tuning fork frequency, the period of the beats increases. In the limit as the frequencies of waves 1 and 2 match perfectly, this period approaches infinity, which means the piano tuner no longer hears beats at all—the piano string is now perfectly tuned.

Scoring Worksheet

The following provides a scoring worksheet and conversion table used for calculating a composite score of the exam.

2016 AP Physics 1 Scoring Worksheet

Section I: Multiple Choice

__________ × 1.0000 = __________

Number Correct (out of 40) — Weighted Section I Score (Do not round)

Section II: Free Response

Question 1 ________ (out of 7) × 0.8888 = ________ (Do not round)

Question 2 ________ (out of 12) × 0.8888 = ________ (Do not round)

Question 3 ________ (out of 12) × 0.8888 = ________ (Do not round)

Question 4 ________ (out of 7) × 0.8888 = ________ (Do not round)

Question 5 ________ (out of 7) × 0.8888 = ________ (Do not round)

Sum = ________

Weighted Section II Score (Do not round)

Composite Score

________ + ________ = ________

Weighted Section I Score + Weighted Section II Score = Composite Score (Round to nearest whole number)

AP Score Conversion Chart
Physics 1

Composite Score Range	AP Score
57-80	5
43-56	4
31-42	3
20-30	2
0-19	1

Question Descriptors and Performance Data

The following contains tables showing the content assessed,
the correct answer, and how AP students performed on each question.

2016 AP Physics 1: Algebra-Based
Question Descriptors and Performance Data

Multiple-Choice Questions

Question	Learning Objectives	Essential Knowledge	Science Practices	Key	% Correct
1	4.A.1.1; 4.A.2.1; 5.D.3.1	4.A.1; 4.A.2; 5.D.3	1.2; 1.4; 6.4; 6.4	B	80
2	3.F.2.1	3.F.2	6.4	A	67
3	3.A.1.1; 3.B.1.1; 5.B.4.1; 5.B.5.4	3.A.1; 3.B.1; 5.B.4; 5.B.5	1.5; 2.2; 6.4; 7.2; 6.4; 7.2; 6.4; 7.2	C	54
4	5.B.3.1; 5.E.1.1	5.B.3; 5.E.1	6.4; 7.2; 6.4	B	39
5	5.D.3.1	5.D.3	6.4	D	46
6	3.A.1.1; 4.A.2.3	3.A.1; 4.A.2	1.5; 2.2; 1.4; 2.2	A	38
7	3.A.3.1; 3.B.1.1; 4.A.2.1	3.A.3; 3.B.1; 4.A.2	6.4; 7.2; 6.4; 7.2; 6.4	C	37
8	5.B.4.2	5.B.4	1.4; 2.1; 2.2	C	30
9	5.B.4.1	5.B.4	6.4	C	67
10	5.B.4.2	5.B.4	1.4; 2.2	B	50
11	5.B.9.3	5.B.9	2.2	C	56
12	5.B.5.2	5.B.5	5.1	D	49
13	3.A.4.2	3.A.4	6.4; 7.2	D	47
14	3.A.1.1; 3.B.1.1; 3.D.2.1; 3.D.2.2; 5.D.1.4	3.A.1; 3.B.1; 3.D.1; 3.D.2; 5.D.1	2.2; 6.4; 2.1; 6.4; 5.1; 6.4	B	38
15	5.D.2.5	5.D.2	2.2	D	36
16	6.D.3.2	6.D.3	6.4	D	33
17	6.B.5.1	6.B.5	1.4	C	33
18	1.B.3.1	1.B.3	6.1	B	36
19	2.B.2.2	2.B.2	2.2	B	36
20	3.A.1.1; 3.B.1.1; 3.C.2.1	3.A.1; 3.B.1; 3.C.2	1.5; 2.2; 6.4; 7.2; 2.2; 6.4	C	44
21	3.A.1.1; 3.D.2.2	3.A.1; 3.D.2	1.5; 6.4	C	37
22	3.B.3.3	3.B.3	2.2	A	22
23	6.D.3.2; 6.D.4.2	6.D.3; 6.D.4	6.4; 2.2	C	62
24	5.D.3.1	5.D.3	6.4	C	40
25	3.A.1.1; 4.B.1.1	3.A.1; 4.B.1	1.5; 2.2; 2.2	D	28
26	3.A.1.1; 4.B.2.2	3.A.1; 4.B.2	1.5; 2.2; 5.1	D	25
27	4.B.1.1; 4.B.2.1	4.B.1; 4.B.2	1.4; 2.2; 2.2	A	26
28	6.D.1.1; 6.D.2.1	6.D.1; 6.D.2	1.4; 5.1	B	32
29	5.B.9.3; 5.C.3.3	5.B.9; 5.C.3	2.2; 6.4; 7.2; 1.4; 2.2	A	65
30	3.A.1.1; 3.A.1.3; 3.A.3.1; 3.B.2.1	3.A.1; 3.A.3; 3.B.2	1.5; 5.1; 6.4; 1.1; 1.4	D	23
31	3.A.4.2; 3.B.1.3	3.A.4; 3.B.1	6.4; 7.2; 1.5; 2.2	B	41
32	3.F.1.1	3.F.1	1.4	D	24
33	3.A.3.1; 3.B.2.1	3.A.3; 3.B.2	6.4; 1.1; 1.4; 2.2	C	24
34	3.A.3.1; 3.B.2.1; 3.B.3.1	3.A.3; 3.B.2; 3.B.3	6.4; 1.1; 1.4; 2.2; 6.4	A	55
35	5.B.3.2	5.B.3	1.4; 2.2	B	32
36	3.B.3.1	3.B.3	6.4	D	17

2016 AP Physics 1: Algebra-Based
Question Descriptors and Performance Data

Question	Learning Objectives	Essential Knowledge	Science Practices	Key	% Correct
131	6.B.4.1; 6.D.3.3	6.B.4; 6.D.3	4.2; 5.1; 7.2; 5.1	A, D	57
132	3.A.2.1; 3.B.2.1	3.A.2; 3.B.2	1.1; 1.1; 1.4	C, D	35
133	5.D.1.5	5.D.1	2.2	B, D	48
134	4.D.2.2	4.D.2	4.2	A, B	27

Free-Response Questions

Question	Learning objectives	Essential Knowledge	Science Practices	Mean Score
1	5.B.3.1; 5.B.3.3; 5.B.4.1; 5.B.4.2; 5.D.2.3; 5.D.2.5	5.B.3; 5.B.4; 5.D.2	2.2; 6.4; 1.4; 2.2; 6.4; 1.4; 2.1; 2.2; 6.4; 7.2; 2.1; 2.2	1.63
2	3.A.1.1; 5.B.3.1; 5.B.3.3; 5.B.4.2; 5.B.5.5	1.A.1; 2.A.1; 3.A.1; 5.B.3; 5.B.4; 5.B.5	1.5; 2.1; 2.2; 2.2; 6.4; 7.2; 1.4; 2.2; 1.4; 2.2; 2.2; 6.4	2.76
3	3.A.1.2; 3.A.1.3; 3.A.2.1; 3.B.1.2; 3.B.2.1; 4.A.2.3; 4.A.3.1; 4.C.2.1; 4.C.2.2; 5.B.5.3	3.A.1; 3.A.2; 3.B.1; 3.B.2; 4.A.2; 4.A.3; 4.C.2; 5.B.5	4.2; 5.1; 1.1; 4.2; 5.1; 1.1; 1.4; 1.4; 2.2; 2.2; 6.4; 1.4; 2.2; 7.2; 1.4; 2.2; 6.4	3.96
4	3.A.1.1; 4.D.2.1; 4.D.3.1; 5.E.1.1; 5.E.1.2	3.A.1; 4.D.2; 4.D.3; 5.E.1; 5.E.2	1.5; 2.1; 2.2; 1.2; 1.4; 2.2; 6.4; 2.2	1.44
5	6.D.2.1; 6.D.5.1	6.D.2; 6.D.5	5.1; 1.2	2.28

AP Physics 1: Algebra-Based

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