From the 2018 Administration

AP® CollegeBoard

AP Physics 1: Algebra-Based

Practice Exam

NOTE: This is a modified version of the 2018 AP Physics 1: Algebra-Based Exam.

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Note: This publication shows the page numbers that appeared in the ***2017–18 AP Exam Instructions*** book and in the actual exam. This publication was not repaginated to begin with page 1.

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Exam Instructions

The following contains instructions taken from the ***2017–18 AP Exam Instructions*** book.

AP Physics 1: Algebra-Based Exam

Regularly Scheduled Exam Date: Tuesday afternoon, May 8, 2018

Late-Testing Exam Date: Thursday morning, May 24, 2018

AP Physics 2: Algebra-Based Exam

Regularly Scheduled Exam Date: Wednesday afternoon, May 9, 2018

Late-Testing Exam Date: Thursday afternoon, May 24, 2018

Section I	**Total Time:** 1 hour and 30 minutes Calculator allowed **Number of Questions:** 50 *(The number of questions may vary slightly depending on the form of the exam.)* **Percent of Total Score:** 50% **Writing Instrument:** Pencil required
Section II	**Total Time:** 1 hour and 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
- ☐ *2017-18 AP Coordinator's Manual*
- ☐ This book—*2017-18 AP Exam Instructions*
- ☐ AP Exam Seating Chart template
- ☐ School Code and Homeschool/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 during the test administration, including breaks"

Before Distributing Exams: Check that the title on all exam covers is ***Physics 1: Algebra-Based*** or ***Physics 2: Algebra-Based***. If there are any exam booklets with a different title, contact the AP coordinator immediately.

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 52 of the *2017-18 AP Coordinator's Manual*. See pages 49–52 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, they must hand copy, date, and sign the release statement on page 51 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 303–304 for a seating chart template and instructions. See the *2017-18 AP Coordinator's Manual* for exam seating requirements (pages 55–58).

Physics 1: Algebra-Based

If you are giving the regularly scheduled exam, say:

It is Tuesday afternoon, May 8, 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 morning, May 24, 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 9, 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 Thursday afternoon, May 24, and you will be taking the AP Physics 2: Algebra-Based Exam.

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

Look at your exam packet and confirm that the exam title is "AP Physics 1: Algebra-Based." Raise your hand if your exam packet contains any title other than "AP Physics 1: Algebra-Based," and I will help you.

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

Look at your exam packet and confirm that the exam title is "AP Physics 2: Algebra-Based." Raise your hand if your exam packet contains any title other than "AP Physics 2: Algebra-Based," and I will help you.

Once you confirm that all students have the correct exam, say:

In a moment, you will open the exam packet. By opening this packet, you agree to all of the AP Program's policies and procedures outlined in the *2017-18 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. Place it on page 1 of your answer sheet on the light blue box near the top right 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.

Listen carefully to all my instructions. I will give you time to complete each step. Please look up after completing each step. Raise your hand if you have any questions.

Give students enough time to complete each step. Don't move on until all students are ready.

Read the statements on the front cover of the Section I booklet. . . .

Sign your name and write today's date. . . .

Now print your full legal name where indicated. . . .

Turn to the back cover of your exam booklet and read it completely. . . .

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. You may never discuss the multiple-choice exam content at any time in any form with anyone, including your teacher and other students. If you disclose the multiple-choice exam content through any means, your AP Exam score will be canceled.

Open your answer sheet to page 2. 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 ______________ . Note Stop Time ______________ .

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. 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. Close your booklet and put your answer sheet on your desk, faceup. 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, faceup. 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 exam content with anyone, and if you disclose the content 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 your pen, 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? . . .

If this is your last AP Exam, you may keep your Student Pack. Place it under your chair for now. Otherwise I will collect all Student Packs. . . .

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, 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 _______________. Note Stop Time _______________.

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, faceup. . . .

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 after the exam (see page 67 of the *2017-18 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 their 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 the free-response exam content with anyone unless it is 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 content 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.

After-Exam Tasks

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.

NOTE: If you administered exams to students with accommodations, review the *2017-18 AP Coordinator's Manual* and the *2017-18 AP SSD Guidelines* for information about completing the NAR form, and returning these exams.

The exam proctor should complete the following tasks if asked to do so by the AP coordinator. Otherwise, the AP coordinator must complete these tasks:

- Complete an Incident Report for any students who used extra paper for the free-response section. (Incident Report forms are provided in the coordinator packets sent with the exam shipments.) **These forms must be completed with a No. 2 pencil.** It is best to complete a single Incident Report for multiple students per exam subject, per administration (regular or late testing), as long as all required information is provided. Include all exam booklets with extra sheets of paper in an Incident Report return envelope (see page 67 of the *2017-18 AP Coordinator's Manual* for complete details).
- Return all exam materials to secure storage until they are shipped back to the AP Program. (See page 26 of the *2017-18 AP Coordinator's Manual* for more information about secure storage.) 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 *2017-18 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.

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.)

CollegeBoard AP

Answer Sheet 2018

AP Number Label
(from Student Pack)

AP FPO X123456789 X

AP Exam Label
(from Section I Booklet)

COMPLETE THIS AREA AT EVERY EXAM. USE NO. 2 PENCIL ONLY

I am aware of and agree to follow the policies and procedures in the *2017-18 Bulletin for AP Students and Parents* to maintain the security of the exam and the validity of my AP score. I understand and accept that my exam score may be canceled if I do not follow these policies and procedures, if I disregard any exam day instructions, or if my exam is administered improperly. I certify that I am the person whose information appears on this answer sheet.

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–Z, –)

C. YOUR AP NUMBER (0–9)

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 (0–9)

G. ONLINE PROVIDER CODE (0–9)

H. AP EXAM I AM TAKING USING THIS ANSWER SHEET — Exam Name: | Form: | Form Code:

801356

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 (0–9)

INTERNATIONAL PHONE

J. SCHOOL YOU ATTEND

SCHOOL CODE (0–9) | 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) (0–9)

M. COLLEGE TO RECEIVE YOUR AP SCORE REPORT

COLLEGE CODE (0–9) — 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	A B C D E F G H I	4	A B C D E F G H I
2	A B C D E F G H I	5	A B C D E F G H I
3	A B C D E F G H I	6	A B C D E F G H I
7	A B C D E F G H I		
8	A B C D E F G H I		
9	A B C D E F G H I		

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

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

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 Computer Science Principles, AP Physics 1, or AP Physics 2

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

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

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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

ZIP OR POSTAL CODE

COUNTRY CODE

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

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 address in accordance with the policies in the *2017-18 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 2018 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 2018. Therefore, the timing indicated here may not be appropriate for a practice exam.

AP® Physics 1: Algebra-Based Exam

SECTION I: Multiple Choice **2018**

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

At a Glance

Total Time
1 hour and 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 4OBP4-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, $k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9\ \mathrm{N{\cdot}m^2/C^2}$
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant, $G = 6.67 \times 10^{-11}\ \mathrm{m^3/kg{\cdot}s^2}$
Speed of light, $c = 3.00 \times 10^8$ m/s	Acceleration due to gravity at Earth's surface, $g = 9.8\ \mathrm{m/s^2}$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$L = I\omega$$

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

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

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

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

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

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

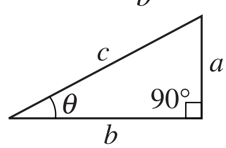
A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

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

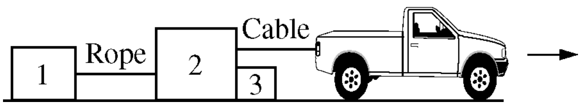
Section I

Time—1 hour and 30 minutes

40 Questions

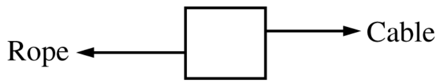
Note: To simplify calculations, you may use $g = 10 \text{ m/s}^2$ in all problems.

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.

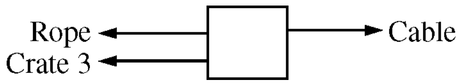


1. The figure above shows a truck pulling three crates across a rough road. Which of the following shows the directions of all the horizontal forces acting on crate 2 ?

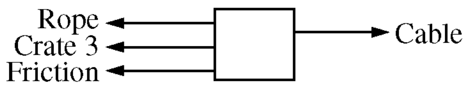
(A)



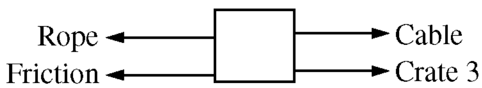
(B)



(C)



(D)



2. Two blocks are on a horizontal, frictionless surface. Block A is moving with an initial velocity of v_0 toward block B, which is stationary, as shown above. The two blocks collide, stick together, and move off with a velocity of $v_0/3$. Which block, if either, has the greater mass?

(A) Block A
(B) Block B
(C) Neither; their masses are the same.
(D) The answer cannot be determined without knowing the mass of one of the blocks.

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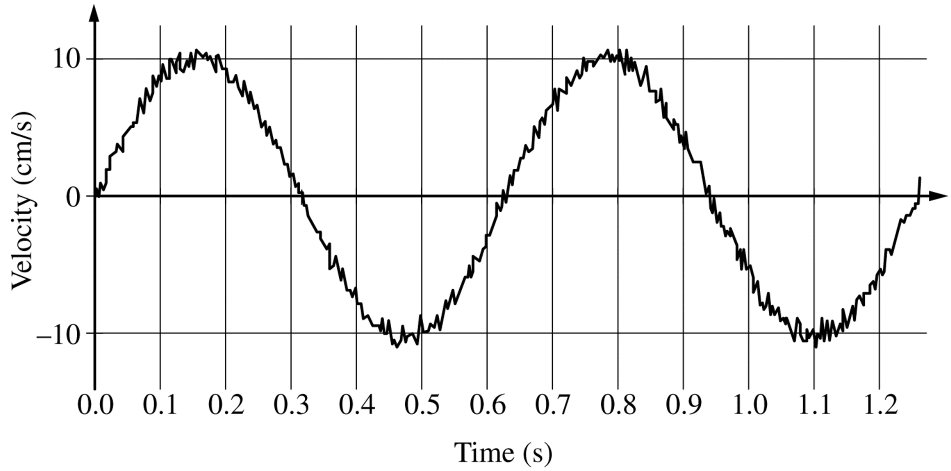
Questions 3-5 refer to the following material.



A student sets an object attached to a spring into oscillatory motion and uses a motion detector to record the velocity of the object as a function of time. A portion of the recorded data is shown in the figure above.

3. The total change in the object's speed between 1.0 s and 1.1 s is most nearly

   (A) zero
   (B) 5 cm/s
   (C) 10 cm/s
   (D) 15 cm/s

4. The acceleration of the object at time $t = 0.7$ s is most nearly equal to which of the following?

   (A) The value of the graph where it crosses the 0.7 s grid line
   (B) The slope of the line connecting the origin and the point where the graph crosses the 0.7 s grid line
   (C) The area under the curve between where the graph crosses the time axis near 0.63 s and time 0.7 s
   (D) The slope of the tangent to a best-fit sinusoidal curve at 0.7 s

5. The frequency of oscillation is most nearly

   (A) 0.63 Hz
   (B) 0.80 Hz
   (C) 1.25 Hz
   (D) 1.60 Hz

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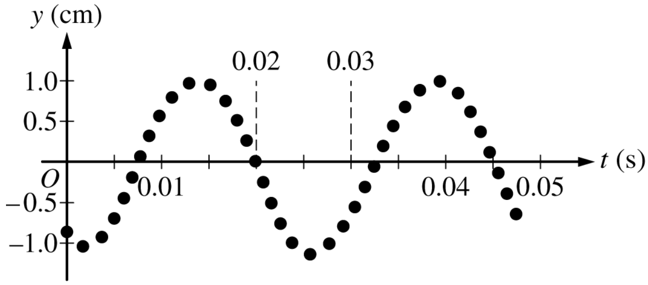
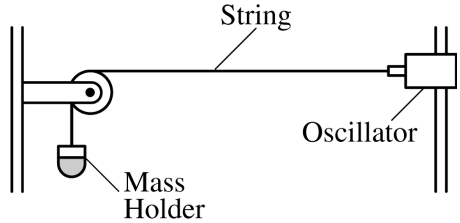


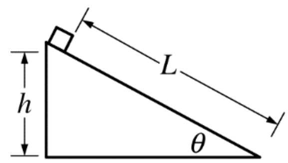
6. One end of a string is fixed in place and the other end is vibrated, allowing a wave to propagate along the string. The vertical position y of a single point on the string is measured at fixed intervals of time t as the wave passes. The graph above shows y as a function of t for the point. A separate measurement indicates that the wave speed on the string is $12\ \text{m/s}$. The wavelength of the wave is most nearly

   (A) 0.0021 m
   (B) 0.15 m
   (C) 0.30 m
   (D) 480 m



7. Using the setup above, a student tests how the tension in a string affects the frequency of the fundamental standing wave (with one antinode). In each trial, with a known mass in the holder, the student adjusts the oscillator frequency to produce the fundamental standing wave. The student notices that as the mass in the holder increases, the string stretches and the total string length, from the oscillator to the mass holder, increases. Which of the following procedures could help the student decide if the string's total length has a <u>separate</u> effect from the tension on the fundamental frequency?

   (A) Repeating the experiment with a string that does not noticeably stretch when the tension is increased
   (B) Repeating the experiment but producing standing waves with two antinodes
   (C) Repeating the experiment using a different distance between the oscillator and pulley
   (D) Repeating the experiment using lighter blocks



8. A box of mass m is initially at rest at the top of a ramp that is at an angle θ with the horizontal. The block is at a height h and length L from the bottom of the ramp. The block is released and slides down the ramp. The coefficient of kinetic friction between the block and the ramp is μ. What is the kinetic energy of the box at the bottom of the ramp?

   (A) mgh
   (B) $\mu mgL\cos\theta$
   (C) $mgh - \mu mgL\cos\theta$
   (D) $mgL - \mu mgh\cos\theta$

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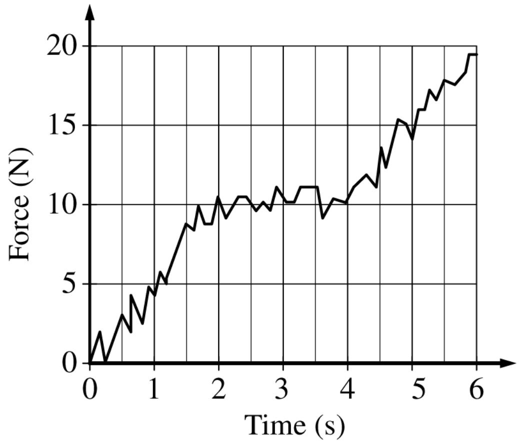
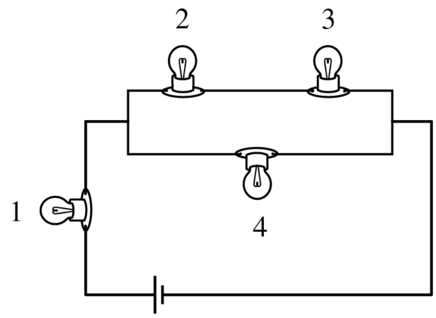


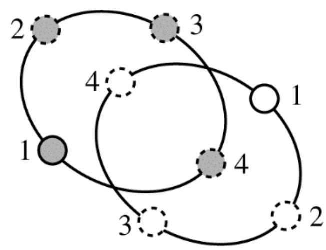
9. During an experiment a student records the net horizontal force exerted on an object moving in a straight line along a horizontal frictionless track. The graph above shows the force as a function of time. Of the following, which is the best approximation of the magnitude of the change in momentum of the object between 0 s and 4 s?

(A) 20 kg•m/s
(B) 30 kg•m/s
(C) 40 kg•m/s
(D) The magnitude of the change in momentum cannot be determined without knowing the mass of the object.



10. The figure above shows four identical lightbulbs connected to a battery. Which of the following correctly ranks the power P dissipated by the lightbulbs?

(A) $P_1 > (P_2 = P_3 = P_4)$
(B) $(P_2 = P_3 = P_4) > P_1$
(C) $P_1 > P_4 > (P_2 = P_3)$
(D) $P_1 = P_2 = P_3 = P_4$



11. The figure above shows the paths of two stars of equal mass as they orbit their common center of mass. The positions of the stars at four different times are labeled in the figure. At which of the positions do the stars have their greatest speed?

(A) Position 2 only
(B) Position 4 only
(C) Positions 1 and 3 only
(D) All of the positions, since the stars move with constant speed

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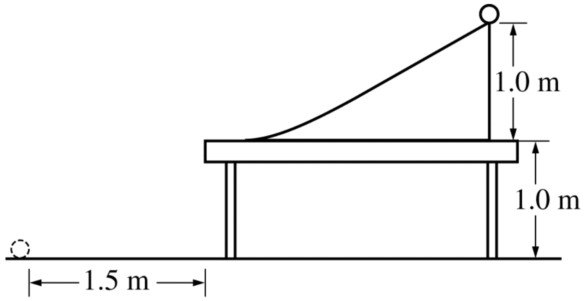
Questions 12-14 refer to the following material.



A cylinder at rest is released from the top of a ramp, as shown above. The ramp is 1.0 m high, and the cylinder rolls down the ramp without slipping. At the bottom of the ramp, the cylinder makes a smooth transition to a small section of a horizontal table and then travels over the edge at a height of 1.0 m above the floor, eventually landing on the floor at a horizontal distance of 1.5 m from the table.

12. As the cylinder rolls down the ramp, how do the potential energy of the cylinder-Earth system and the kinetic energy of the cylinder change, if at all?

	Potential Energy of Cylinder-Earth System	Kinetic Energy of Cylinder
(A)	Stays the same	Increases
(B)	Stays the same	Decreases
(C)	Decreases	Increases
(D)	Decreases	Decreases

13. After the cylinder leaves the table, but before it lands, how do the rotational kinetic energy and translational kinetic energy of the cylinder change, if at all?

	Rotational Kinetic Energy	Translational Kinetic Energy
(A)	Increases	Increases
(B)	Increases	Stays the same
(C)	Stays the same	Increases
(D)	Stays the same	Stays the same

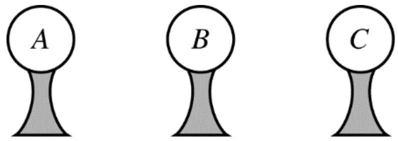
14. A sphere with the same mass and radius as the original cylinder, but a smaller rotational inertia, is released from rest from the top of the ramp. K_s and K_c are the sphere's and the cylinder's total kinetic energy at the bottom of the ramp, respectively. How do K_s and K_c compare, and why?

(A) $K_s < K_c$, because the sphere will gain less rotational kinetic energy.

(B) $K_s < K_c$, because the sphere has a greater acceleration and therefore has less time to gain kinetic energy.

(C) $K_s = K_c$, because both objects accelerate at the same rate.

(D) $K_s = K_c$, because the gravitational force does equal work on each object as it rolls down the ramp.



15. Three identical metal spheres on insulating stands are initially isolated from each other, as shown above. The spheres *A*, *B*, and *C* carry electric charges $+12Q$, $-12Q$, and $+12Q$, respectively. Whenever two of the spheres come into contact, each sphere ends up with the same net charge as the other sphere. Spheres *A* and *B* are brought into contact with each other and separated. Spheres *A* and *C* are then brought into contact with each other and separated. Which of the following correctly shows the final charge on each sphere?

	A	*B*	*C*
(A)	0	0	$+12Q$
(B)	$+4Q$	$+4Q$	$+4Q$
(C)	$+6Q$	0	$+6Q$
(D)	$+12Q$	$+12Q$	$-12Q$

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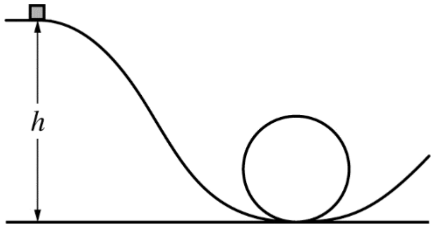
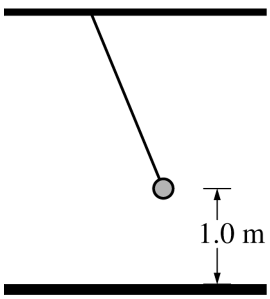


Note: Figure not drawn to scale.

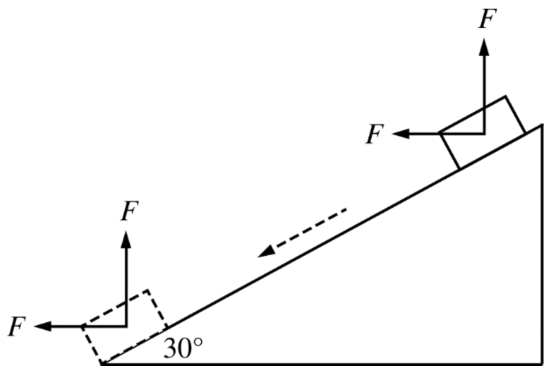
16. A small block slides without friction along a track toward a circular loop. The block has more than enough speed to remain firmly in contact with the track as it goes around the loop. The magnitude of the block's acceleration at the top of the loop is

(A) zero
(B) greater than zero but less than g
(C) equal to g
(D) greater than g



17. A 0.5 kg pendulum bob is raised to 1.0 m above the floor, as shown in the figure above. The bob is then released from rest. When the bob is 0.8 m above the floor, its speed is most nearly

(A) 5 m/s
(B) 4 m/s
(C) 2 m/s
(D) 1 m/s



18. A block is released from rest and slides down a frictionless ramp inclined at 30° from the horizontal. When the block reaches the bottom, the block-Earth system has mechanical energy E_0. The experiment is repeated, but now horizontal and vertical forces of magnitude F are exerted on the block while it slides, as shown above. When the block reaches the bottom, the mechanical energy of the block-Earth system

(A) is greater than E_0
(B) is equal to E_0
(C) is less than E_0
(D) cannot be determined without knowing F

19. An apple is released from rest 500 m above the ground. Due to the combined forces of air resistance and gravity, it has a speed of 40 m/s when it reaches the ground. What percentage of the initial mechanical energy of the apple-Earth system was dissipated due to air resistance? Take the potential energy of the apple-Earth system to be zero when the apple reaches the ground.

(A) 16%
(B) 40%
(C) 60%
(D) 84%

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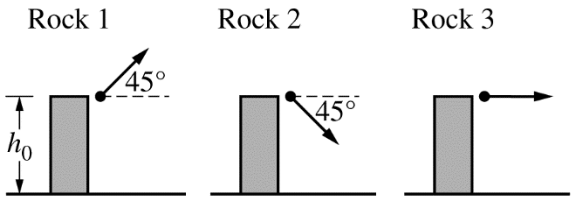
Questions 20-21 refer to the following material.



Three identical rocks are launched with identical speeds from the top of a platform of height h_0. The rocks are launched in the directions indicated above.

20. Which of the following correctly relates the magnitude v_y of the vertical component of the velocity of each rock immediately before it hits the ground?

(A) $(v_{y1} = v_{y2}) > v_{y3}$

(B) $v_{y1} > v_{y3} > v_{y2}$

(C) $v_{y2} > v_{y3} > v_{y1}$

(D) $v_{y1} = v_{y2} = v_{y3}$

21. Rock 1, of mass m, reaches a maximum height h_{max} after being launched. During the time between the instant rock 1 is launched from height h_0 and the instant it returns to height h_0, the work done on the rock by the gravitational force is

(A) 0

(B) $-mgh_0$

(C) $-mg(h_{max} - h_0)$

(D) $2mg(h_{max} - h_0)$

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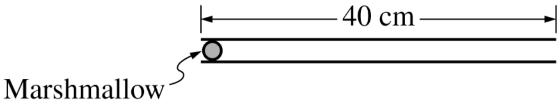
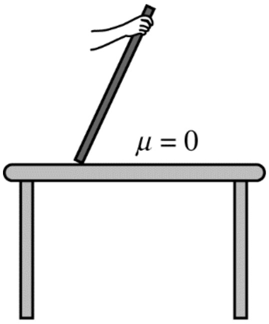


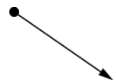
22. A 2.5 g marshmallow is placed in one end of a 40 cm pipe, as shown in the figure above. A person blows into the left end of the pipe to eject the marshmallow from the right end. The average net force exerted on the marshmallow while it is in the pipe is 0.7 N. The speed of the marshmallow as it leaves the pipe is most nearly

(A) 4.7 m/s
(B) 11 m/s
(C) 15 m/s
(D) 280 m/s



23. A meterstick is held as shown above and then released from rest. The tabletop has negligible friction. Which figure below best indicates the path of the center of mass of the meterstick as it falls?

(A) 

(B) 

(C) 

(D) 

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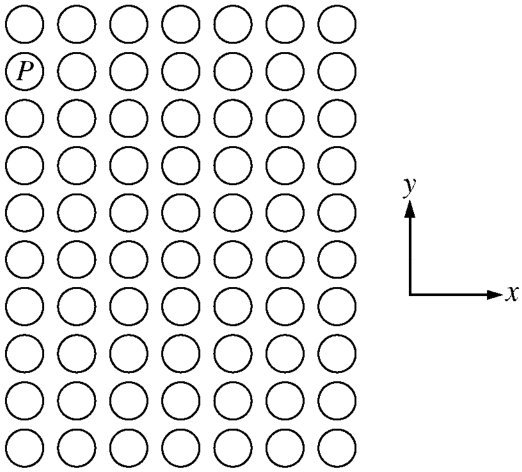

Figure 1

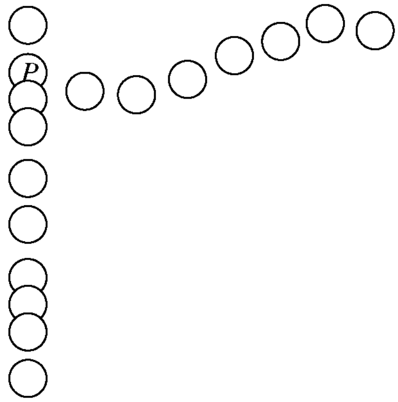

Figure 2

24. Figure 1 above represents atoms in a solid material. A particle hits atom P and the atom vibrates, disturbing nearby atoms. Figure 2 represents just the vertical and horizontal rows containing atom P and shows the propagation of the disturbance along them. Which of the following statements correctly indicates the direction of atom P's vibration and the type of wave along each row?

	P's Vibration	Wave Along Vertical Row	Wave Along Horizontal Row
(A)	Along y axis	Longitudinal	Transverse
(B)	Along y axis	Transverse	Longitudinal
(C)	Along x axis	Longitudinal	Transverse
(D)	Along x axis	Transverse	Longitudinal

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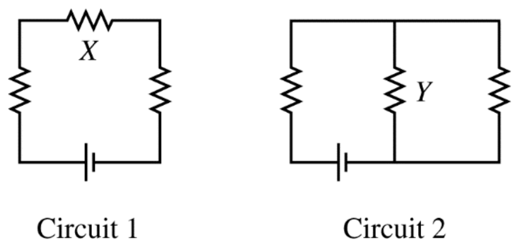
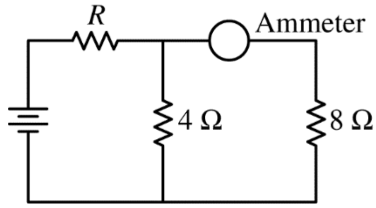


25. The two circuits shown above contain identical resistors and batteries. Which of the following best explains why resistors *X* and *Y* dissipate the same power?

    (A) Resistors *X* and *Y* have the same potential difference across them because each is the second resistor in its circuit.
    (B) Both circuits have identical batteries and contain the same number of identical resistors.
    (C) Although each circuit has a different total current, the current through an individual resistor depends only on its resistance.
    (D) Compared to circuit 1, the total current through circuit 2 is twice as much, but only half that current flows through resistor *Y*.



26. In the circuit above, the current through the ammeter is 2 A. What is the current through the resistor of unknown resistance *R* ?

    (A) 6 A
    (B) 4 A
    (C) 3 A
    (D) The current cannot be determined without knowing the value of *R*.

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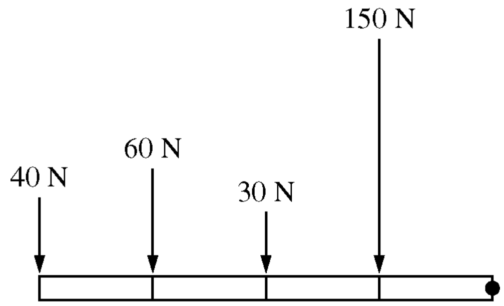
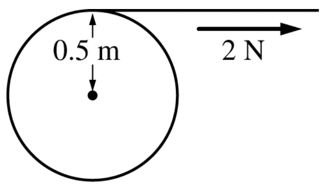


27. The figure above represents a stick of uniform density that is attached to a pivot at the right end and has equally spaced marks along its length. Any one of the four forces shown can be exerted on the stick as indicated. Which force will create the largest rate of change in the stick's angular momentum?

(A) The 30 N force
(B) The 40 N force
(C) The 60 N force
(D) The 150 N force



28. A disk with radius of 0.5 m is free to rotate around its center without friction. A string wrapped around the disk is pulled, as shown above, exerting a 2 N force tangent to the edge of the disk for 1 s. If the disk starts from rest, what is its angular speed after 1 s?

(A) 0 rad/s
(B) 1 rad/s
(C) 4 rad/s
(D) It cannot be determined without knowing the rotational inertia of the disk.

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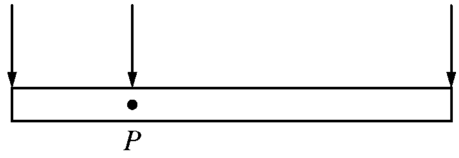

Top View

29. The figure above shows a rod that is fixed to a horizontal surface at pivot P. The rod is initially rotating without friction in the counterclockwise direction. At time t, three forces of equal magnitude are applied to the rod as shown. Which of the following is true about the angular speed and direction of rotation of the rod immediately after time t ?

	Angular Speed	Direction of Rotation
(A)	Decreasing	Counterclockwise
(B)	Decreasing	Clockwise
(C)	Increasing	Counterclockwise
(D)	Increasing	Clockwise

30. Two systems are in oscillation: a simple pendulum swinging back and forth through a very small angle and a block oscillating on a spring. The block-spring system takes twice as much time as the pendulum to complete one oscillation. Which of the following changes could make the two systems oscillate with the same period?

(A) Increasing the mass of the pendulum bob
(B) Increasing the angle through which the pendulum swings by a small amount
(C) Decreasing the mass of both the block and the pendulum bob
(D) Shortening the pendulum

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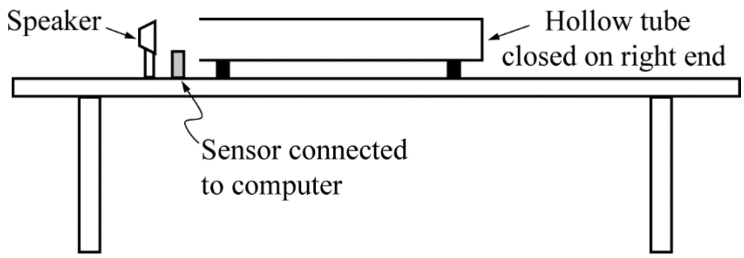
Questions 31-32 refer to the following material.



Students use a speaker connected to a sine wave generator to project sound waves into the open left end of a tube that is closed on the right end. The speaker is very close to the tube. A sensor is used to measure the pressure differences created by the sound and the results are displayed on a computer. The entire apparatus is in a sealed chamber that can be filled with different gases.

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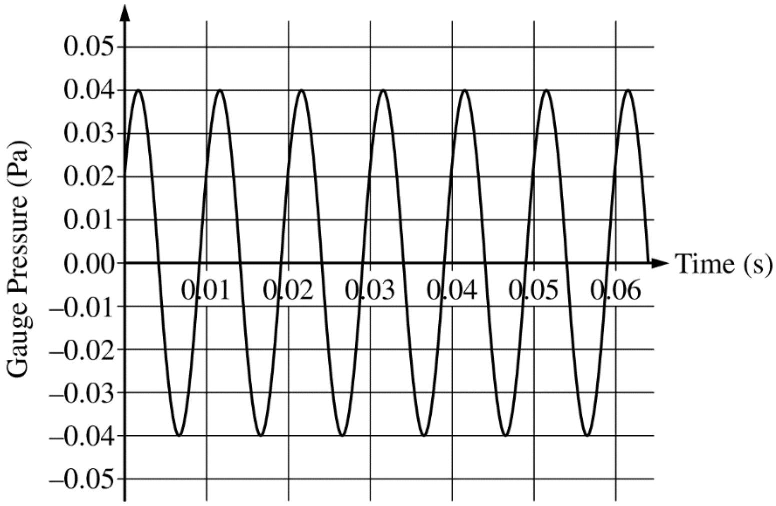

31. The students vary the frequency of the sound until the maximum loudness from the tube is achieved. The graph above represents the computer display of gauge pressure (the amount by which the pressure is above or below atmospheric pressure) as a function of time. What are the amplitude and frequency of the wave?

	Amplitude	Frequency
(A)	0.04 Pa	0.01 Hz
(B)	0.04 Pa	100 Hz
(C)	0.08 Pa	0.01 Hz
(D)	0.08 Pa	100 Hz

32. The chamber is now filled with a gas that has an unknown speed of sound. The students find that the lowest frequency at which they can hear a maximum in the sound level is 200 Hz. If the students slowly increase the frequency, what is the next frequency at which the sensor would measure a maximum in the sound level?

(A) 300 Hz
(B) 400 Hz
(C) 600 Hz
(D) 800 Hz

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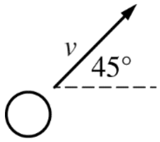
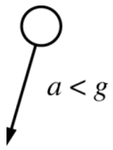
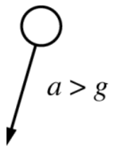
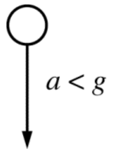
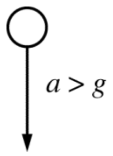


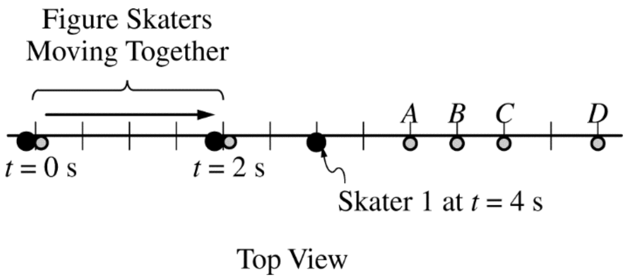
33. A hollow plastic ball is projected into the air. There is significant air resistance opposing the ball's motion, so the magnitude of the ball's acceleration is <u>not</u> equal to g. At time t, the ball is moving up and to the right at an angle of $45°$ to the horizontal, as shown above. Which of the following best shows the magnitude a and the direction of the ball's acceleration at time t ?

(A) 

(B) 

(C) 

(D) 



34. At time $t = 0$ two figure skaters are moving together over ice with negligible friction, as shown above. Skater 1, represented by the large black dot, is twice as massive as skater 2, represented by the gray dot. At $t = 2$ s the skaters push off of one another. The location of skater 1 is shown at $t = 4$ s . At $t = 4$ s , skater 2 is located at which of the labeled points?

(A) Point A
(B) Point B
(C) Point C
(D) Point D

35. A charged sphere located at the origin of the xy-plane exerts a force of magnitude F on a charged particle located at $(+d,\ 0)$. The sphere will exert a force $F/2$ on the particle if the particle is moved to which of the following locations?

(A) $(+2d,\ 0)$
(B) $(+d,\ +d)$
(C) $(+d/2,\ 0)$
(D) $(0,\ -d)$

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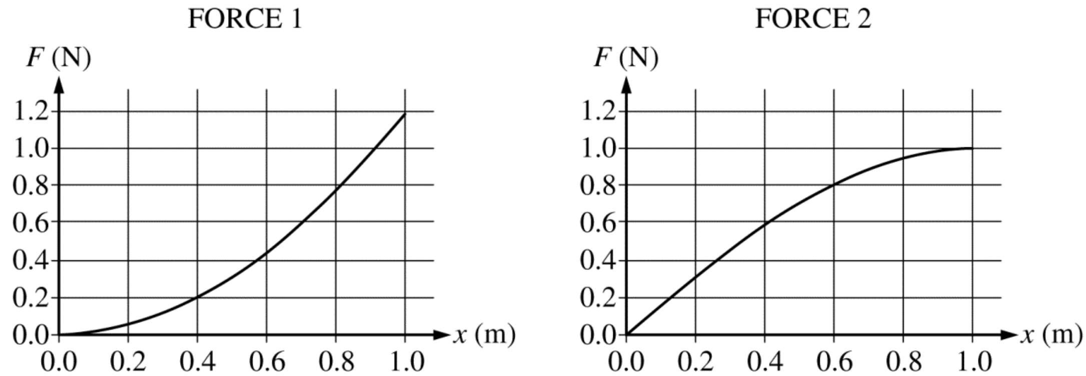

36. The graphs above show the magnitude F of a force exerted on an object as a function of the object's position x for two trials in an experiment. W_1 and W_2 are the work done on the object by force 1 and force 2, respectively. How do W_1 and W_2 compare, and why?

(A) $W_1 > W_2$, because the maximum value of force 1 is greater than the maximum value of force 2.
(B) $W_1 > W_2$, because the slope of force 1's graph increases, while the slope of force 2's graph decreases.
(C) $W_1 < W_2$, because the average value of force 1 is smaller than the average value of force 2.
(D) $W_1 < W_2$, because at the midpoint, $x = 0.5$ m, the value of force 1 is less than the value of force 2.

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GO ON TO THE NEXT PAGE.

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. A water-skier with weight $F_g = mg$ moves to the right with acceleration a. A horizontal tension force T is exerted on the skier by the rope, and a horizontal drag force F_d is exerted by the water on the ski. The water also exerts a vertical lift force L on the skier. Which of the following are correct relationships between the forces exerted on the skier-ski system? Select two answers.

(A) $T - F_d = ma$

(B) $L - F_g = ma$

(C) $L - F_g = 0$

(D) $T - F_d = 0$

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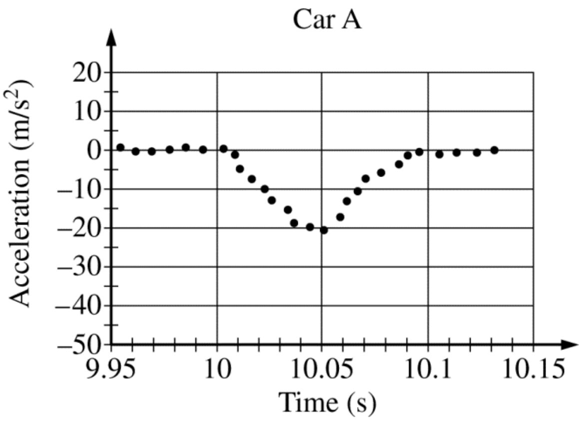

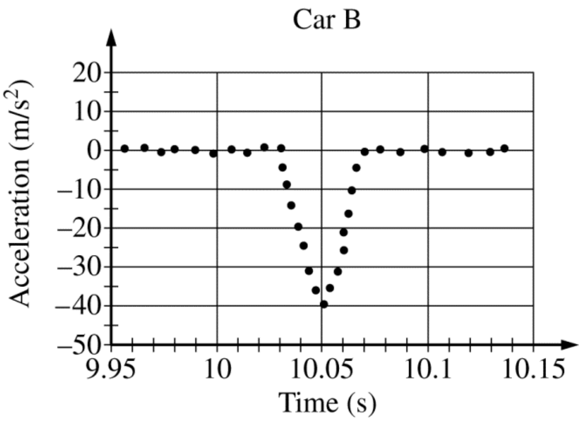

132. Two model cars, A and B, have the same mass but different bumpers. The acceleration of each car during its collision with a wall is measured, and the data are shown in the graphs above. Which of the following statements about the collisions are correct? Select two answers.

(A) Both cars reach their maximum speed at 10.05 s.
(B) The cars experience approximately the same impulse.
(C) Car B experiences a nonzero force for a longer time than car A.
(D) The change in momentum for car B occurs over a shorter period of time than for car A.

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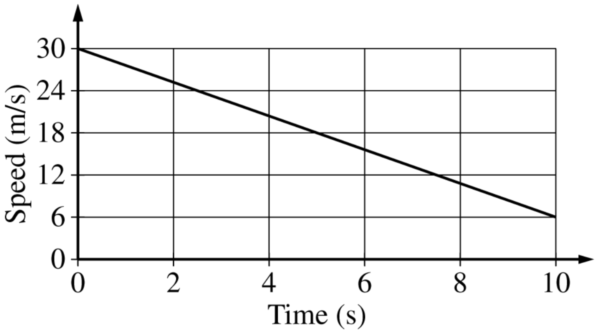

133. The graph above shows the speed of a truck as it moves along a straight, level road. Which of the following describe a method to determine the distance *d* the truck travels during the 10 s time interval shown? Select two answers.

(A) Multiply the average speed of $18\ \text{m/s}$ by the 10 s travel time.

(B) Multiply half the initial speed of $30\ \text{m/s}$ by the 10 s travel time.

(C) Calculate the slope of the line in the graph to determine the acceleration *a* and then use $d = (1/2)at^2$, where *t* is the travel time.

(D) Calculate the area under the line in the graph.

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134. A vehicle lands on Mars and explores its surface. The average gravitational field on the surface of Mars is $3.7\ \text{N/kg}$. The weight of the vehicle is defined as the gravitational force exerted on it. Which of the following statements are true about the vehicle's weight? Select two answers.

(A) The vehicle's weight was constant until it reached the surface of Mars.
(B) The vehicle's weight increased while it was descending to the surface of Mars.
(C) The vehicle's weight always equals the normal force exerted by Mars on the vehicle while it is landing.
(D) The vehicle weighs less on the surface of Mars than on the surface of Earth.

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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 2018 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

2018

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

At a Glance

Total Time
1 hour and 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 4OBP4-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, $k = 1/4\pi\varepsilon_0 = 9.0 \times 10^{9}\ \mathrm{N{\cdot}m^2/C^2}$
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant, $G = 6.67 \times 10^{-11}\ \mathrm{m^3/kg{\cdot}s^2}$
Speed of light, $c = 3.00 \times 10^{8}$ m/s	Acceleration due to gravity at Earth's surface, $g = 9.8\ \mathrm{m/s^2}$

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

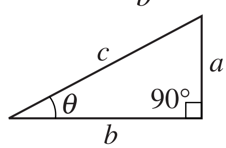
- A = area
- C = circumference
- V = volume
- S = surface area
- b = base
- h = height
- ℓ = length
- w = width
- r = radius

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

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

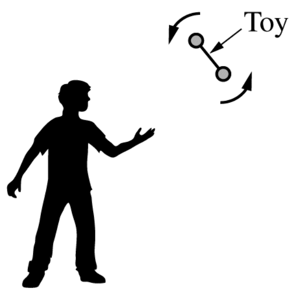
$\cos\theta = \frac{b}{c}$

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



PHYSICS 1
Section II
Time—1 hour and 30 minutes
5 Questions

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.

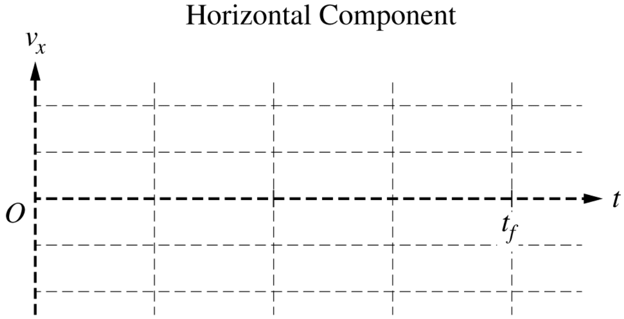


1. (7 points, suggested time 13 minutes)

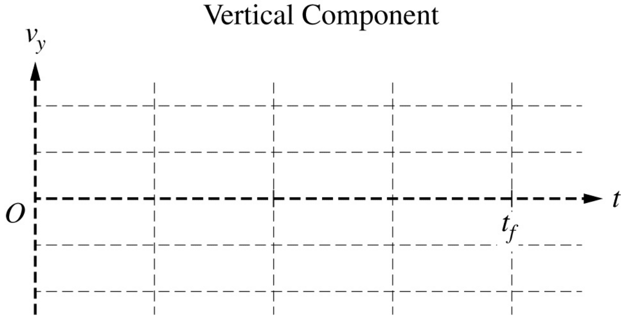
A toy consists of two identical solid spheres connected by a string with negligible mass. The toy is thrown at an angle above the horizontal (not straight up) such that the string remains taut and both spheres are revolving counterclockwise in a vertical plane around the center of the string, as shown above.

(a) Sketch graphs of the horizontal and vertical components of the velocity of the center of the string as a function of time, from the instant the spheres are released at time $t = 0$ until the instant the system returns to its initial height at time t_f. Take the positive direction to be toward the right for the horizontal component and the positive direction to be upward for the vertical component.

Horizontal Component



Vertical Component



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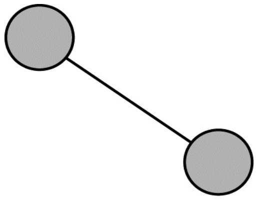
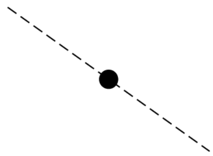


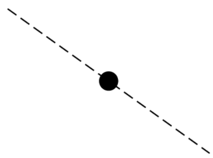
(b) The figure above shows the toy at the instant the center of the string reaches the top of its trajectory. This is a side view: the sphere on the left is higher than the sphere on the right.

i. On the dot below, which represents the left sphere only, draw and label the forces (not components) exerted on the left sphere at this instant. Represent each force by a distinct arrow starting on, and pointing away from, the dot. The dashed line is drawn at the same angle as the string.



Left Sphere

ii. On the dot below, which represents the whole toy (the spheres-string system), draw and label the forces (not components) that act on the system at this instant. Represent each force by a distinct arrow starting on, and pointing away from, the dot. The dashed line is drawn at the same angle as the string.



Whole Toy

iii. When the toy was released, the center of the string was moving with an initial speed of $15\ \text{m/s}$ at a $60°$ angle above the horizontal. Calculate the speed of the center of the string at the instant shown above, when the center of the string reaches the top of its trajectory.

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2. (12 points, suggested time 25 minutes)

A heavy lab cart moves with kinetic energy K_{init} on a track and collides with a lighter lab cart that is initially at rest. The carts bounce off each other but the collision is not perfectly elastic, causing the two-cart system to lose kinetic energy K_{lost}. A student wonders if the fraction of kinetic energy lost from the two-cart system during the collision $\left(\dfrac{K_{\text{lost}}}{K_{\text{init}}}\right)$ depends on the speed of the first cart before the collision and plans to perform an experiment.

(a) The student hypothesizes that a greater fraction of kinetic energy is lost from the system during the collision when the speed of the first cart is greater.

Briefly state one reason the hypothesis might be correct.

(b) Design an experimental procedure that could be used to test the student's hypothesis. Assume equipment usually found in a school physics laboratory is available.

In the table below, list the quantities that would be measured and the equipment that would be used to measure each quantity. Also, define a symbol to represent each quantity. You do not need to use every row and may add additional rows as needed.

Quantity to be Measured	Symbol	Equipment for Measurement

Describe the overall procedure to be used, referring to the table above. Provide enough detail so that another student could replicate the experiment. As needed, use the symbols defined in the table and/or include a simple diagram of the setup. Be sure to address how experimental uncertainty could be reduced.

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(c) Describe how the experimental data could be analyzed to confirm or disconfirm the hypothesis that a greater fraction of kinetic energy is lost from the system during the collision when the speed of the first cart is greater. Include a description or example of any equations, data tables, graphs, or other representations that could be used.

(d) Consider a different scenario in which the carts stick together after the collision. The masses of the heavier and lighter cart are m_1 and m_2, respectively. Derive an expression for the fraction of kinetic energy lost $\left(\frac{K_{lost}}{K_{init}}\right)$ during the collision. Express your answer in terms of m_1 and m_2.

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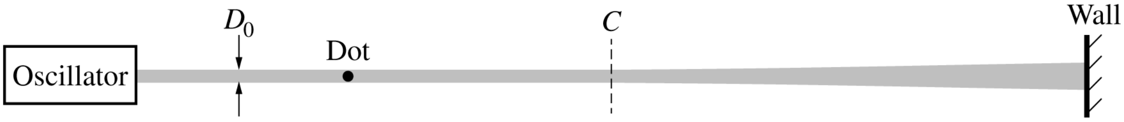


Note: Figure not drawn to scale.

3. (12 points, suggested time 25 minutes)

As shown above, the left end of a horizontal string is attached to an oscillator and the right end is attached to a wall. The string's midpoint is labeled C, and a dot has been painted on the left half of the string. The left half of the string is uniformly thick, with diameter D_0, while the right half of the string gradually increases in thickness from the midpoint C to the wall. The string is made of a material with uniform density (mass per unit volume).

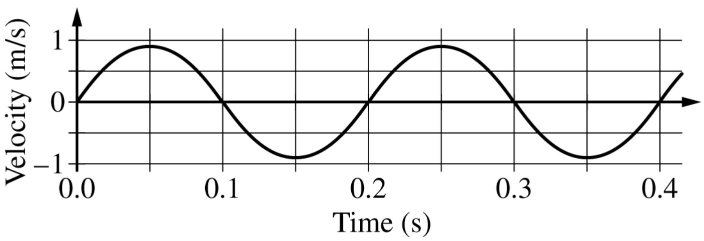
(a) The oscillator shakes the left end of the string up and down, creating waves traveling to the right with speed v_0. A student observes that every wave crest approaching the midpoint C passes through C but gradually slows down on the right half of the string.

i. On which half of the string, if either, do the waves have a longer wavelength?

____ Left half ____ Right half ____ Same wavelength on both halves

Briefly explain your reasoning.

ii. The graph below represents the vertical velocity of the dot on the left half of the string as a function of time.



Describe how you could use the graph to estimate the amplitude of the waves at the dot's location. You do NOT have to actually calculate the amplitude.

(b) In a different experiment, the oscillator shakes the left end of the string up and down at a rate of 50 cycles per second. The leading edge of the wave reaches the midpoint C, which is 0.75 m from the left end of the string, 0.030 second after the oscillator starts shaking the string. Calculate the wavelength of the wave on the left half of the string.

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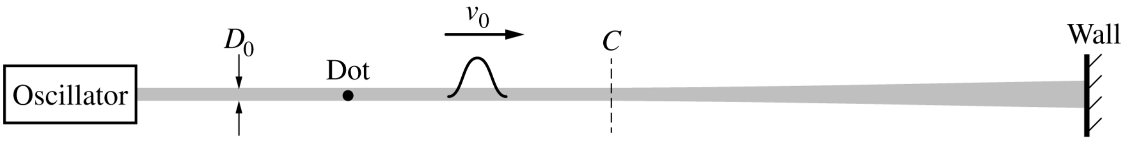


<u>Note</u>: Figure not drawn to scale.

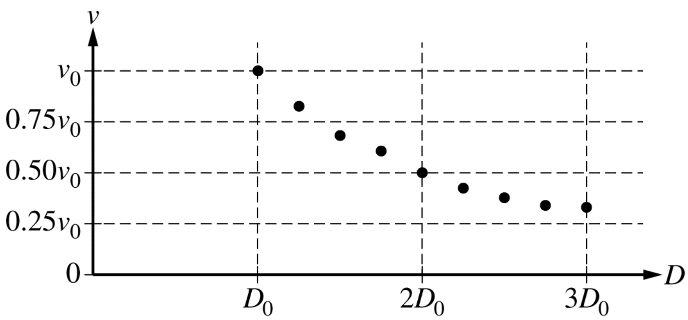
Later, the student uses the oscillator to create a single pulse with initial speed v_0 at the left end of the string, as shown above. The student wants to quantify the observation that the pulse slows down on the right half of the string. The student comes up with the following equation relating the string's diameter D at a given point on the string to the speed v of the pulse at that point: $v = v_0\left(\frac{D_0}{D}\right)$.

(c) Is the equation consistent with the observation that the pulse slows down on the right half of the string?

____ Yes ____ No

Briefly explain your reasoning.

(d) Using frame-by-frame analysis of video of the pulse, the student plots the speed v of the pulse as a function of the string diameter D, as shown below.



Are the data in the graph consistent with the student's equation above?

____ Yes ____ No

Briefly explain your answer.

Question 3 continues on the next page.

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Note: Figure not drawn to scale.

(e) The figure above shows only the right half of the string. The solid line represents the shape of the wave pulse when its peak reaches point X, which is to the right of the midpoint C. Draw the pulse when it reaches point Y. Your drawing should clearly indicate whether the width of the pulse at point Y is greater than, equal to, or less than the width of the pulse at point X.

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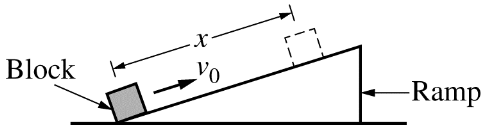
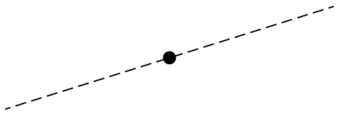
4. (7 points, suggested time 13 minutes)

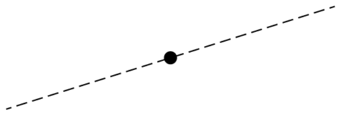
A student strikes a block at the bottom of a ramp, giving it an initial speed v_0 up the ramp, as shown at right. There is friction between the ramp and the block as it slides a distance x up the ramp and then slides back down.



(a) On the dots below, which represent the block as it is sliding up the ramp and down the ramp, draw and label the forces (not components) exerted on the block. Represent each force by a distinct arrow starting on, and pointing away from, the dot. The dashed lines are drawn at the same angle as the surface of the ramp.



Up the Ramp



Down the Ramp

(b) The block takes time t_{up} to slide up the ramp a distance x. The block then takes time t_{down} to slide back down to the bottom of the ramp, where it has speed v_f. Is t_{down} greater than, equal to, or less than t_{up}?

____ $t_{\text{down}} > t_{\text{up}}$ ____ $t_{\text{down}} = t_{\text{up}}$ ____ $t_{\text{down}} < t_{\text{up}}$

In a clear, coherent paragraph-length response that may also contain figures and/or equations, explain your reasoning. If you need to draw anything other than what you have shown in part (a) to assist in your response, use the space below. Do NOT add anything to the figures in part (a).

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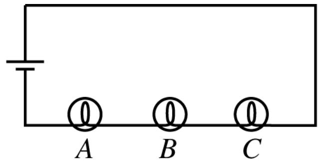

Figure 1

5. (7 points, suggested time 13 minutes)

Students in a physics lab use a battery and three identical lightbulbs to construct the circuit shown in Figure 1 above. The brightness of each bulb increases when the current through the bulb increases.

(a) Which bulb, if any, is the brightest?

____ *A* ____ *B* ____ *C* ____ All bulbs have the same brightness.

Briefly explain your reasoning in terms of current and/or potential difference.

(b) The students observe the brightness of bulbs *A*, *B*, and *C*. The students then add a fourth lightbulb *D,* with a larger resistance than bulbs *A*, *B*, and *C*, as shown in Figure 2 below.

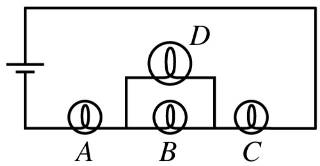

Figure 2

i. Is bulb *A* now brighter than, dimmer than, or the same brightness as it was in the circuit in Figure 1 ?

____ Brighter ____ Dimmer ____ Same brightness

Briefly explain your reasoning.

ii. Is bulb *B* now brighter than, dimmer than, or the same brightness as it was in the circuit in Figure 1 ?

____ Brighter ____ Dimmer ____ Same brightness

Briefly explain your reasoning.

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GO ON TO THE NEXT PAGE.

(c) Bulbs A, B, and C each have resistance $10\ \Omega$, while bulb D has a resistance of $30\ \Omega$. In the circuit shown in Figure 2, the current through bulb D is measured to be 0.20 A. Calculate the potential difference across bulb A.

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GO ON TO THE NEXT PAGE.

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

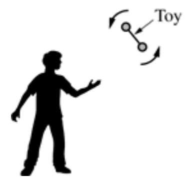
Question 1: C
Question 2: B
Question 3: B
Question 4: D
Question 5: D
Question 6: C
Question 7: A
Question 8: C
Question 9: B
Question 10: C
Question 11: B
Question 12: C
Question 13: C
Question 14: D
Question 15: C
Question 16: D
Question 17: C
Question 18: A
Question 19: D
Question 20: A
Question 21: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

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**

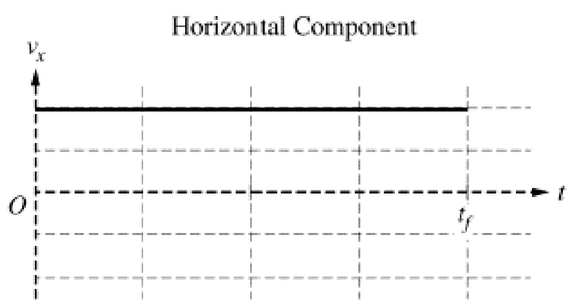


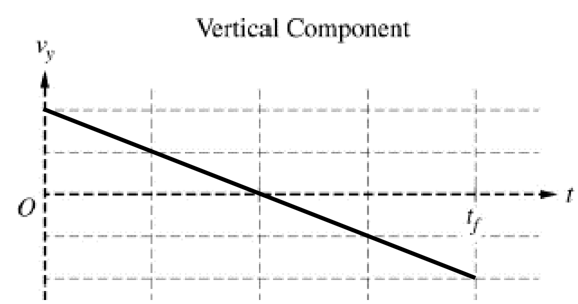
A toy consists of two identical solid spheres connected by a string with negligible mass. The toy is thrown at an angle above the horizontal (not straight up) such that the string remains taut and both spheres are revolving counterclockwise in a vertical plane around the center of the string, as shown above.

(a) LO / SP: 4.A.2.1 / 6.4; 4.A.2.3 / 1.4, 2.2
2 points

Sketch graphs of the horizontal and vertical components of the velocity of the center of the string as a function of time, from the instant the spheres are released at time $t = 0$ until the instant the system returns to its initial height at time t_f. Take the positive direction to be toward the right for the horizontal component and the positive direction to be upward for the vertical component.

Example graphs:





Horizontal component: For a non-zero horizontal line		1 point
Vertical component: For a non-vertical line with a negative slope that crosses the horizontal axis near $t_f/2$ and reaches t_f		1 point
<u>Note</u>: Any part of the sketched graph beyond t_f is ignored.		

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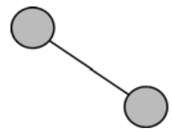
Question 1 (continued)

Distribution of points

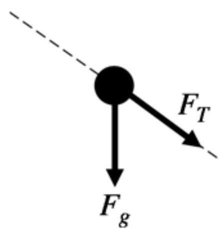
(b) LO / SP: 3.A.4.3 / 1.4; 3.B.2.1 / 1.1; 4.A.2.1 / 6.4; 4.A.2.3 / 1.4, 2.2; 4.A.3.2 / 1.4
5 points



The figure above shows the toy at the instant the center of the string reaches the top of its trajectory. This is a side view: the sphere on the left is higher than the sphere on the right.

i 2 points

On the dot below, which represents the left sphere only, draw and label the forces (not components) exerted on the left sphere at this instant. Represent each force by a distinct arrow starting on, and pointing away from, the dot. The dashed line is drawn at the same angle as the string.

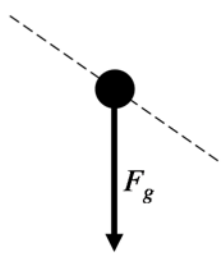


Left Sphere

For a gravitational force with correct direction and label		1 point
For a tension force with correct direction and label		1 point
Note: A maximum of one point may be earned if there are any extraneous forces.		

ii 1 point

On the dot below, which represents the whole toy (the spheres-string system), draw and label the forces (not components) that act on the system at this instant. Represent each force by a distinct arrow starting on, and pointing away from, the dot. The dashed line is drawn at the same angle as the string.



Whole Toy

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Question 1 (continued)

Distribution of points

(b)(ii) continued

For a vector pointing downward representing the gravitational force with no extraneous forces		1 point
Note: A label is not required, since the use of labels is assessed in part (b)(i).		

iii 2 points

When the toy was released, the center of the string was moving with an initial speed of $15\ \text{m/s}$ at a $60°$ angle above the horizontal. Calculate the speed of the center of the string at the instant shown above, when the center of the string reaches the top of its trajectory.

For attempting to find the horizontal component of velocity Note: See examples below. This point is earned for the wrong use of trig functions if it is clear it is being used to find the horizontal component, but not awarded if it's not clear which component the trig function is referring to, or for stating that the vertical component is zero.		1 point
For a correct numerical answer for horizontal velocity with correct units		1 point
Examples: 0 points: $v\sin\theta = 13\ \text{m/s}$ (No clear indication of an attempt to find the horizontal component) 1 point: $v_x = v\sin\theta = 13\ \text{m/s}$ (An attempt to find the horizontal component is implied by the v_x term) 1 point: $v\cos\theta$ (An attempt to find the horizontal component is implied by the $\cos\theta$ term) 1 point: $v\cos\theta = 7.5$ (Correct numerical answer with no units) 1 point: $7.5\ \text{m/s}$ (Correct answer with units, but no work shown) 2 points: $15\cos 60 = 7.5\ \text{m/s}$ (Correct answer with units) 2 points: $15\cos 60\ \text{m/s}$ (Correct answer with units)		

Question 1 (continued)

Learning Objectives (LO)

LO 3.A.4.3: The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton’s third law to identify forces. [See Science Practice 1.4]

LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See Science Practices 1.1, 1.4, 2.2]

LO 4.A.2.1: The student is able to make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time. [See Science Practice 6.4]

LO 4.A.2.3: The student is able to create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system. [See Science Practices 1.4, 2.2]

LO 4.A.3.2: The student is able to use visual or mathematical representations of the forces between objects in a system to predict whether or not there will be a change in the center-of-mass velocity of that system. [See Science Practice 1.4]

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Question 2

12 points total **Distribution of points**

A heavy lab cart moves with kinetic energy K_{init} on a track and collides with a lighter lab cart that is initially at rest. The carts bounce off each other but the collision is not perfectly elastic, causing the two-cart system to lose kinetic energy K_{lost}. A student wonders if the fraction of kinetic energy lost from the two-cart system during the collision $\left(\frac{K_{lost}}{K_{init}}\right)$ depends on the speed of the first cart before the collision and plans to perform an experiment.

(a) LO / SP: 5.D.1.4 / 4.2, 6.4
1 point

The student hypothesizes that a greater fraction of kinetic energy is lost from the system during the collision when the speed of the first cart is greater.

Briefly state one reason the hypothesis might be correct.

For a valid statement relating the speed of cart and dissipation of mechanical energy Note for pre-reading: Response does not have to address the fractional loss of kinetic energy (points are earned for this distinction in later parts).		1 point
Examples of valid statements: More damage when going faster Slower collision means compression and decompression during collision happen without permanent deformation Examples of invalid statements: Higher fraction of K is lost at higher speeds Because more kinetic energy is lost		

(b) LO / SP: 3.A.1.2 / 4.2; 5.D.1.4 / 4.2
5 points

Design an experimental procedure that could be used to test the student's hypothesis. Assume equipment usually found in a school physics laboratory is available.

In the table below, list the quantities that would be measured and the equipment that would be used to measure each quantity. Also, define a symbol to represent each quantity. You do not need to use every row and may add additional rows as needed.

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Question 2 (continued)

Distribution of points

Quantity to be Measured	Symbol	Equipment for Measurement

Describe the overall procedure to be used, referring to the table above. Provide enough detail so that another student could replicate the experiment. As needed, use the symbols defined in the table and/or include a simple diagram of the setup. Be sure to address how experimental uncertainty could be reduced.

For measuring the speed of both carts before and after collision Note: It is not necessary to measure the initial speed of the cart that is at rest.		1 point
For measuring the mass of the carts (or calculating mass ratio using conservation of momentum, which may be stated later)		1 point
For equipment and measurements consistent with procedure as described or drawn in diagram (e.g., motion detectors in the right places to measure speed of both carts)		1 point
For varying the speed (making speed the independent variable) of the first cart in a feasible experiment that could be done in a school lab. Note: "Varying the speed" means at least 2 trials (to test hypothesis), and "feasible" means that equipment is used appropriately for each measurement.		1 point
For attempting to reduce uncertainty, e.g., multiple trials for a given initial speed of cart 1, or trials involving at least three different initial speeds		1 point

Example:

Quantity to be Measured	Symbol	Equipment for Measurement
Initial speed of heavy cart (H)	v_{iH}	Motion sensor (MS1)
Final speed of heavy cart	$v_{f\,H}$	Motion sensor (MS1)
Mass of heavy cart	m_H	Triple beam balance
Final speed of light cart (L)	$v_{f\,L}$	Motion sensor (MS2)
Mass of light cart	m_L	Triple beam balance

Measure the mass of each cart with the triple beam balance. Set the carts and motion sensors on the track. With the motion sensors recording, push the heavy cart toward the light cart so that they collide. Record the motion sensors readings for the speeds of the heavy cart immediatly before the collision, and the speeds of both carts immediately after the collision. Repeat 8 times, varying the force with which the heavy cart is pushed so that a wide range of initial velocities for the heavy cart are used.

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Question 2 (continued)

Distribution of points

(c) LO / SP: 4.C.1.1 / 1.4, 2.2; 5.B.4.2 / 1.4, 2.2; 5.D.1.4 / 5.1
3 points

Describe how the experimental data could be analyzed to confirm or disconfirm the hypothesis that a greater fraction of kinetic energy is lost from the system during the collision when the speed of the first cart is greater. Include a description or example of any equations, data tables, graphs, or other representations that could be used.

For a correct indication of how initial and final total kinetic energy would be calculated from the raw data		1 point
For using the difference between initial and final total kinetic energy to determine the kinetic energy lost		1 point
For a description of how the calculated <u>fractional</u> energy losses would be used to confirm or disconfirm the hypothesis		1 point

Example:

For each trial, calculate the initial kinetic energy of the heavy cart using $K_{\text{init}} = \frac{1}{2} m_{\text{H}} v_{\text{iH}}^2$.

Also calculate the final kinetic energy $K_f = \frac{1}{2} m_{\text{H}} v_{\text{f H}}^2 + \frac{1}{2} m_{\text{L}} v_{\text{f L}}^2$.

Make a graph of $K_{\text{lost}} / K_{\text{init}} = \left(K_{\text{init}} - K_f \right) / K_{\text{init}}$ as a function of v_{iH}.

If a positive trend is seen in the data, the hypothesis is confirmed.

(d) LO / SP: 4.C.1.1 / 1.4, 2.2; 5.B.4.2 / 1.4, 2.2; 5.D.2.5 / 2.2
3 points

Consider a different scenario in which the carts stick together after the collision. The masses of the heavier and lighter cart are m_1 and m_2, respectively. Derive an expression for the fraction of kinetic energy lost $\left(\frac{K_{\text{lost}}}{K_{\text{init}}} \right)$ during the collision. Express your answer in terms of m_1 and m_2.

For using momentum conservation to find v_f in terms of v_i, or the ratio of post-collision to pre-collision speed		1 point
For a correct expression for final kinetic energy (or consistent with v_f found from conservation of momentum) OR a correct expression for the fractional energy loss in terms of m_1, m_2, the initial speed of the heavy cart, and the final speed of the two-cart system		1 point
A correct expression for fraction of kinetic energy lost: $\frac{m_2}{m_1 + m_2}$ or $1 - \frac{m_1}{m_1 + m_2}$ <u>Note</u>: The above point is not earned if the answer includes any variables other than m_1 and m_2		1 point

Question 2 (continued)

Learning Objectives (LO)

LO 3.A.1.2: The student is able to design an experimental investigation of the motion of an object. [See Science Practice 4.2]

LO 4.C.1.1: The student is able to calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy. [See Science Practices 1.4, 2.1, and 2.2]

LO 5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. [See Science Practices 1.4, 2.1, and 2.2]

LO 5.D.1.4: The student is able to design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome. [See Science Practices 4.2, 5.1, 5.3, and 6.4]

LO 5.D.2.5: The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values. [See Science Practices 2.1 and 2.2]

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Question 3

12 points total | **Distribution of points**

Note: Figure not drawn to scale.

As shown above, the left end of a horizontal string is attached to an oscillator and the right end is attached to a wall. The string's midpoint is labeled C, and a dot has been painted on the left half of the string. The left half of the string is uniformly thick, with diameter D_0, while the right half of the string gradually increases in thickness from the midpoint C to the wall. The string is made of a material with uniform density (mass per unit volume).

(a) LO / SP: 3.A.1.1 / 1.5, 2.1, 2.2; 3.B.3.1 / 6.4, 7.2; 3.B.3.4 / 2.2, 6.2; 6.B.4.1 / 5.1, 7.2
5 points

The oscillator shakes the left end of the string up and down, creating waves traveling to the right with speed v_0. A student observes that every wave crest approaching the midpoint C passes through C but gradually slows down on the right half of the string.

i 2 points

On which half of the string, if either, do the waves have a longer wavelength?

____ Left half ____ Right half ____ Same wavelength on both halves

Briefly explain your reasoning.

Correct answer: "Left half" Note: A maximum of 1 point may be earned if the wrong selection is made.		
For stating that the frequency stays the same		1 point
For stating that, since the speed of the wave decreases as it moves to the right, the wavelength must decrease as well, or for using $\lambda \propto v$ or $v = f\lambda$		1 point

Alternate solution		
For using reasoning that applies to a pulse (the leading edge is slower than trailing edge, so the trailing edge "catches up to" the leading edge and wavelength decreases)		2 points

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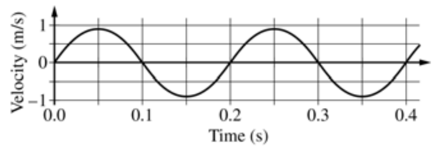
Question 3 (continued)

Distribution of points

(a) continued

ii 3 points

The graph below represents the vertical velocity of the dot on the left half of the string as a function of time.



Describe how you could use the graph to estimate the amplitude of the waves at the dot's location. You do NOT have to actually calculate the amplitude.

For using the area under the velocity vs. time curve.		1 point
For correctly or incorrectly relating the area under the curve to the amplitude OR identifying a specific area (in terms of range of times, "humps", cycles, etc.)		1 point
For correctly identifying a quarter cycle, or "half a hump", as the area or displacement corresponding to the amplitude (or any correct relationship between cycles and amplitude)		1 point
Examples: 1 point: Unspecified area: "Use the area under the curve." 2 points: Any area specified: "Use the area under the curve from t = 0 to t = 0.4 s" "Area under a full hump because that's a full period." "Area under a the curve for 1/4 period" (only 2 points because didn't specify what period corresponds to on the graph) 3 points: Correct area (quarter cycle, OR half cycle with statement that it's twice the amplitude): "The area under half a hump"		

Alternate solution based on $v_{\max} = \omega A$		
For using $v_{\max} = \omega A$		1 point
For indicating how ω *can be determined from the graph (e.g.,* $\omega = \dfrac{2\pi}{T}$*, where* T *corresponds to a complete cycle)*		1 point
For a correct algebraic expression for amplitude (e.g., $\dfrac{v_{\max}T}{2\pi}$*)*		1 point

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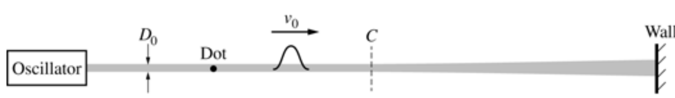
Question 3 (continued)

Distribution of points

(b) LO / SP: 3.A.1.1 / 1.5, 2.1, 2.2; 6.B.4.1 / 5.1
3 points

In a different experiment, the oscillator shakes the left end of the string up and down at a rate of 50 cycles per second. The leading edge of the wave reaches the midpoint C, which is 0.75 m from the left end of the string, 0.030 second after the oscillator starts shaking the string. Calculate the wavelength of the wave on the left half of the string.

For calculating wave speed $(v = d/t)$		1 point
For implicitly or explicitly using $f = 50$ Hz		1 point
For calculating wavelength using $\lambda = v/f$		1 point
Example: $v = \dfrac{0.75\text{ m}}{0.030\text{ s}} = 25\text{ m/s}$ $\lambda = \dfrac{v}{f} = \dfrac{25\text{ m/s}}{50\text{ s}^{-1}} = 0.5\text{ m}$		



Note: Figure not drawn to scale.

Later, the student uses the oscillator to create a single pulse with initial speed v_0 at the left end of the string, as shown above. The student wants to quantify the observation that the pulse slows down on the right half of the string. The student comes up with the following equation relating the string's diameter D at a given point on the string to the speed v of the pulse at that point: $v = v_0\left(\dfrac{D_0}{D}\right)$.

(c) LO / SP: 3.A.1.1 / 1.5, 2.2
1 point

Is the equation consistent with the observation that the pulse slows down on the right half of the string?
____ Yes ____ No
Briefly explain your reasoning.

Correct answer: "Yes"
Note: If the wrong selection is made, the explanation is not graded.

For stating that as D increases, v decreases		1 point

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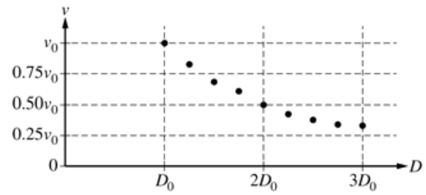
Question 3 (continued)

Distribution of points

(d) LO / SP: 3.A.1.1 / 1.5, 2.2
1 point

Using frame-by-frame analysis of video of the pulse, the student plots the speed v of the pulse as a function of the string diameter D, as shown below.



Are the data in the graph consistent with the student's equation above?
____ Yes ____ No
Briefly explain your answer.

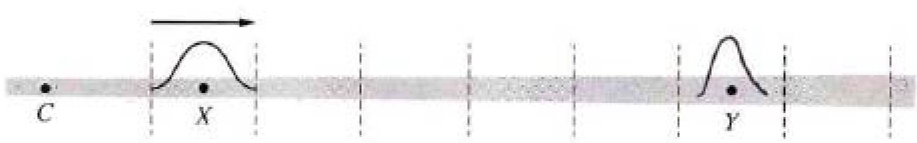
Correct answer: "Yes"		
<u>Note</u>: If the wrong selection is made, no credit can be earned.		
For stating that the data agree with the equation because of the downward trend in the data, or for stating that v decreases as D increases (inverse relationship), or for comparing calculated values from the equation with the data in the graph		1 point

(e) LO / SP: 6.A.1.2 / 1.2
2 points

<u>Note:</u> Figure not drawn to scale.

The figure above shows only the right half of the string. The solid line represents the shape of the wave pulse when its peak reaches point X, which is to the right of the midpoint C. Draw the pulse when it reaches point Y. Your drawing should clearly indicate whether the width of the pulse at point Y is greater than, equal to, or less than the width of the pulse at point X.

Example:



<u>Note:</u> Figure not drawn to scale.

For a pulse with similar overall shape as the original		1 point
For a pulse that is narrower <u>Note</u>: The height is not considered for earning this point.		1 point

Question 3 (continued)

Learning Objectives (LO)

LO 3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations. [See Science Practices 1.5, 2.1, and 2.2]

LO 3.B.3.1: The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. [See Science Practices 6.4 and 7.2]

LO 3.B.3.4: The student is able to construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force. [See Science Practices 2.2 and 6.2]

LO 6.A.1.2: The student is able to describe representations of transverse and longitudinal waves. [See Science Practice 1.2]

LO 6.B.4.1: The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples. [See Science Practices 4.2, 5.1, and 7.2]

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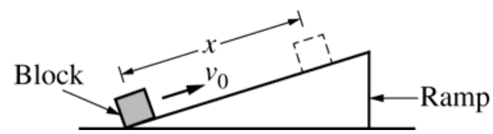
Question 4

7 points total **Distribution of points**

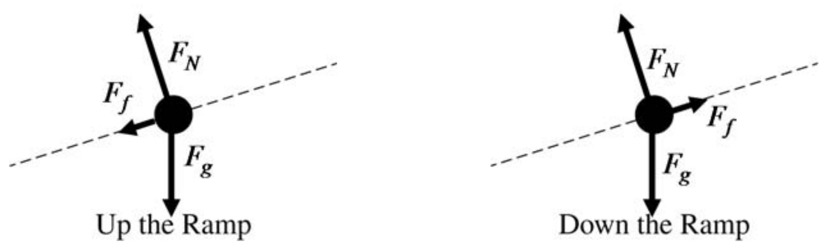
A student strikes a block at the bottom of a ramp, giving it an initial speed v_0 up the ramp, as shown at right. There is friction between the ramp and the block as it slides a distance x up the ramp and then slides back down.



(a) LO / SP: 3.A.2.1 / 1.1; 3.B.2.1 / 1.1, 1.4
2 points

On the dots below, which represent the block as it is sliding up the ramp and down the ramp, draw and label the forces (not components) exerted on the block. Represent each force by a distinct arrow starting on, and pointing away from, the dot. The dashed lines are drawn at the same angle as the surface of the ramp.

Example:



For a labeled friction force vector in the correct direction in both diagrams		1 point
For labeled gravitational and normal forces in the correct directions in both diagrams, with no extraneous forces		1 point

(b) LO / SP: 2.B.1.1 / 2.2; 3.A.1.1 / 1.5, 2.2; 3.B.1.1 / 6.4, 7.2; 3.B.1.3 / 1.5, 2.2; 3.B.2.1 / 1.1, 1.4, 2.2
5 points

The block takes time t_{up} to slide up the ramp a distance x. The block then takes time t_{down} to slide back down to the bottom of the ramp, where it has speed v_f. Is t_{down} greater than, equal to, or less than t_{up}?

____ $t_{down} > t_{up}$ ____ $t_{down} = t_{up}$ ____ $t_{down} < t_{up}$

In a clear, coherent paragraph-length response that may also contain figures and/or equations, explain your reasoning. If you need to draw anything other than what you have shown in part (a) to assist in your response, use the space below. Do NOT add anything to the figures in part (a).

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Question 4 (continued)

Distribution of points

Correct Answer: $t_{\text{down}} > t_{\text{up}}$

Note: The response is graded even if an incorrect selection is made.

For stating that the magnitude of the net force on the block is greater when it is sliding up the ramp than when it is sliding down the ramp because the direction of the frictional force changes while the direction of the component of the gravitational force along the ramp does not (this can be implied) OR a description of the net force consistent with the free-body diagrams (FBDs) in part (a)		1 point
For stating that the magnitude of acceleration of the block while sliding up the ramp is greater than that when sliding down, OR a description of acceleration consistent with the FBDs in part (a)		1 point
For a justification that v_f is less than v_0, OR average v up is greater than average v down (e.g., speed changes more on way up than on way down because acceleration is greater on the way up and the same distance covered and final/initial speed on way up/down is zero), OR a description of final and initial speeds consistent with the FBDs in part (a)		1 point
For a correct *argument* that, if v_f is less than v_0 or the average speed up is greater than the average speed down, then t_{down} is greater than t_{up}. (This argument could include a kinematic equation.) Note: Student cannot earn this point even if justification is consistent with an incorrect FBD in part (a)		1 point
For a logical, relevant, and internally consistent argument that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response		1 point
Note: A maximum of 4 of 5 points (first 3 points plus 5th point) can be earned if the FBDs in part (a) are incorrect (e.g., friction force is in the same direction in both FBDs)		

Alternate solution using work/energy reasoning for 1st two points of part (b)		
For correctly applying work-energy to up/down ramp (or, indicating block-Earth system has the same potential energy at the beginning and end)		1 point
For correct treatment of energy loss to friction		1 point

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Question 4 (continued)

Learning Objectives (LO)

LO 2.B.1.1: The student is able to apply $F = mg$ to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems. [See Science Practices 2.2 and 7.2]

LO 3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations. [See Science Practices 1.5, 2.1, and 2.2]

LO 3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [See Science Practice 1.1]

LO 3.B.1.1: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension. [See Science Practices 6.4 and 7.2]

LO 3.B.1.3: The student is able to reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. [See Science Practices 1.5 and 2.2]

LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See Science Practices 1.1, 1.4, and 2.2]

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Question 5

7 points total **Distribution of points**

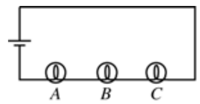

Figure 1

Students in a physics lab use a battery and three identical lightbulbs to construct the circuit shown in Figure 1 above. The brightness of each bulb increases when the current through the bulb increases.

(a) LO / SP: 5.C.3.1 / 6.4
1 point

Which bulb, if any, is the brightest?
____ *A* ____ *B* ____ *C* ____ All bulbs have the same brightness.
Briefly explain your reasoning in terms of current and/or potential difference.

Correct answer: "All bulbs have the same brightness"		
Note: The response does not earn credit if an incorrect selection is made.		
For correct checkbox and assertion that current (rate of charge flow) is the same throughout the circuit. Note: For this point to be earned, statement must include current and/or potential difference (i.e., "because they are in series" is not sufficient).		1 point
Examples: The current through the light bulbs is the same everywhere within a series circuit regardless of their proximity to the battery. Because the potential difference across each bulb is the same.		

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Question 5 (continued)

Distribution of points

(b) LO / SP: 5.B.9.3 / 2.2, 6.4; 5.C.3.1 / 6.4; 5.C.3.3 / 1.4, 2.2
3 points

The students observe the brightness of bulbs *A*, *B*, and *C*. The students then add a fourth lightbulb *D*, with a larger resistance than bulbs *A*, *B*, and *C*, as shown in Figure 2 below.

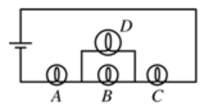

Figure 2

i 2 points

Is bulb *A* now brighter than, dimmer than, or the same brightness as it was in the circuit in Figure 1 ?
____ Brighter ____ Dimmer ____ Same brightness
Briefly explain your reasoning.

Correct answer: "Brighter"		
<u>Note</u>: The response is graded even if an incorrect selection is made.		
For recognizing that the addition of lightbulb *D* reduces the equivalent resistance of the circuit		1 point
For correctly stating that the overall current (i.e., current through battery) is greater in the modified circuit		1 point

ii 1 point

Is bulb *B* now brighter than, dimmer than, or the same brightness as it was in the circuit in Figure 1 ?
____ Brighter ____ Dimmer ____ Same brightness
Briefly explain your reasoning.

Correct answer: "Dimmer"
<u>Note</u>: The response does not earn credit if an incorrect selection is made.

For an argument that the current is now split between bulb *B* and bulb *D*, which tends to lower the current through bulb *B* <u>Note</u>: It is not necessary to address change in current through the battery.		1 point
Alternate Solution		
For an argument that the potential difference across both bulb A and bulb C increases <u>and</u> the potential difference of the battery remains constant, which causes the potential difference across bulb B to decrease due to conservation of energy (Kirchhoff's Loop Rule)		*1 point*

Question 5 (continued)

Distribution of points

(c) LO / SP: 5.B.9.3 / 2.2, 6.4; 5.C.3.1 / 6.4; 5.C.3.3 / 1.4, 2.2
3 points

Bulbs *A*, *B*, and *C* each have resistance $10\ \Omega$, while bulb *D* has a resistance of $30\ \Omega$. In the circuit shown in Figure 2, the current through bulb *D* is measured to be 0.20 A. Calculate the potential difference across bulb *A*.

Reasoning using current:		
For correctly calculating the current through bulb *B* (0.6 A)		1 point
For an implicit or explicit calculation of the total current consistent with previous step (0.8 A)		1 point
For a potential difference across bulb *A* consistent with previous steps and with correct units: 8 V		1 point

Reasoning using potential difference:		
For correctly calculating the potential difference across bulb *D* and recognizing (explicitly or implicitly) that it is equal to the potential difference across bulb *B* (6 V)		1 point
For explicitly or implicitly determining the ratio R_A/R_{BD} (4/3)		1 point
For a potential difference across bulb *A* consistent with previous steps and with correct units: 8 V		1 point

Learning Objectives (LO)

LO 5.B.9.3: The student is able to apply conservation of energy (Kirchhoff's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch. [See Science Practices 2.2, 6.4, 7.2]

LO 5.C.3.1: The student is able to apply conservation of electric charge (Kirchhoff's junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed. [See Science Practices 6.4, 7.2]

LO 5.C.3.3: The student is able to use a description or schematic diagram of an electrical circuit to calculate unknown values of current in various segments or branches of the circuit. [See Science Practices 1.4, 2.2]

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Scoring Worksheet

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

2018 AP Physics 1 Scoring Worksheet

Section I: Multiple Choice

__________ $\times$ 1.0000 = __________
Number Correct (out of 40) — Weighted Section I Score (Do not round)

Section II: Free Response

Question 1 ________ (out of 7) $\times$ 0.8888 = ________ (Do not round)

Question 2 ________ (out of 12) $\times$ 0.8888 = ________ (Do not round)

Question 3 ________ (out of 12) $\times$ 0.8888 = ________ (Do not round)

Question 4 ________ (out of 7) $\times$ 0.8888 = ________ (Do not round)

Question 5 ________ (out of 7) $\times$ 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
61-80	5
48-60	4
36-47	3
24-35	2
0-23	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.

2018 AP Physics 1: Algebra-Based
Question Descriptors and Performance Data

Multiple-Choice Questions

Question	Learning Objectives	Essential Knowledge	Science Practices	Key	% Correct
1	3.A.3.1; 3.B.2.1	3.A.3; 3.B.2	6.4; 1.4	C	89
2	5.D.2.5	5.D.2	2.2	B	52
3	3.A.1.1; 3.A.1.3	3.A.1; 3.A.1	1.5; 2.2; 5.1	B	90
4	3.A.1.1; 3.A.1.3; 3.B.3.3	3.A.1; 3.A.1; 3.B.3	1.5; 2.2; 5.1; 2.2; 5.1	D	67
5	3.B.3.3	3.B.3	2.2; 5.1	D	54
6	6.B.2.1; 6.B.4.1	6.B.2; 6.B.4	1.4; 5.1	C	62
7	6.D.3.1	6.D.3	4.2	A	47
8	3.B.2.1; 4.C.1.1; 4.C.2.2; 5.B.4.2; 5.B.5.5	3.B.2; 4.C.1; 4.C.2; 5.B.4; 5.B.5	2.2; 2.2; 2.2; 2.2; 2.2; 6.4	C	68
9	4.B.2.2	4.B.2	5.1	B	36
10	5.B.9.3; 5.C.3.1; 5.C.3.3	5.B.9; 5.C.3; 5.C.3	6.4; 7.2; 6.4; 7.2; 1.4	C	64
11	3.E.1.1; 3.E.1.2; 5.B.3.1; 5.B.4.1	3.E.1; 3.E.1; 5.B.3; 5.B.4	6.4; 7.2; 1.4; 2.2; 6.4; 7.2; 6.4; 7.2	B	51
12	5.B.4.1; 5.B.4.2; 5.B.5.4	5.B.4; 5.B.4; 5.B.5	6.4; 1.4; 6.4	C	83
13	3.E.1.1; 4.C.1.2	3.E.1; 4.C.1	6.4; 6.4	C	48
14	5.A.2.1; 5.B.4.2	5.A.2; 5.B.4	6.4; 1.4; 2.1; 2.2	D	37
15	1.B.1.1; 1.B.1.2; 5.A.2.1	1.B.1; 1.B.1; 5.A.2	6.4; 6.4; 6.4	C	63
16	3.A.1.1; 3.B.1.3; 3.B.2.1	3.A.1; 3.B.1; 3.B.2	1.5; 2.2; 1.5; 2.2; 1.1; 1.4; 2.2	D	43
17	5.B.4.2	5.B.4	1.4; 2.1	C	49
18	3.E.1.1; 4.C.2.1; 5.B.5.4	3.E.1; 4.C.2; 5.B.5	6.4; 7.2; 6.4; 6.4; 7.2	A	44
19	4.C.1.1; 4.C.1.2; 5.B.3.2; 5.B.5.5	4.C.1; 4.C.1; 5.B.3; 5.B.5	1.4; 2.1; 2.2; 6.4; 1.4; 2.2; 2.2; 6.4	D	32
20	3.A.1.1	3.A.1	1.5; 2.2	A	37
21	3.E.1.1; 3.E.1.4; 4.C.1.1; 4.C.2.2; 5.B.4.2	3.E.1; 3.E.1; 4.C.1; 4.C.2; 5.B.4	6.4; 2.2; 1.4; 2.2; 1.4; 2.2; 1.4; 2.2	A	36
22	3.A.1.1; 5.B.5.5	3.A.1; 5.B.5	2.2; 2.2	C	39
23	3.B.1.1; 3.B.2.1; 4.A.2.1	3.B.1; 3.B.2; 4.A.2	6.4; 1.1; 1.4; 6.4	C	41
24	6.A.1.1	6.A.1	6.2	A	47
25	1.B.1.1; 5.B.9.3; 5.C.3.3	1.B.1; 5.B.9; 5.C.3	6.4; 2.2; 6.4; 7.2; 1.4; 2.2	D	47
26	5.C.3.1; 5.C.3.3	5.C.3; 5.C.3	6.4; 1.4; 2.2	A	36
27	3.F.1.2; 4.D.1.1	3.F.1; 4.D.1	1.4; 1.4	C	58
28	3.F.2.1; 4.D.3.1	3.F.2; 4.D.3	6.4; 2.2	D	43
29	3.F.2.1	3.F.2	6.4	A	32
30	3.B.3.1	3.B.3	6.4; 7.2	C	32
31	6.A.3.1; 6.B.1.1	6.A.3; 6.B.1	1.4; 1.4	B	69
32	6.D.4.2	6.D.4	2.2	C	29
33	3.A.1.1; 3.A.3.1	3.A.1; 3.A.3	1.5; 2.2; 6.4; 7.2	B	33
34	4.A.1.1; 4.A.2.1; 4.A.3.2; 5.D.2.5; 5.D.3.1	4.A.1; 4.A.2; 4.A.3; 5.D.2; 5.D.3	1.4; 6.4; 6.4; 1.4; 2.2; 6.4	D	25
35	3.C.2.1	3.C.2	6.4	B	31
36	5.B.5.3	5.B.5	1.4; 2.2; 6.4	C	42

2018 AP Physics 1: Algebra-Based
Question Descriptors and Performance Data

Question	Learning Objectives	Essential Knowledge	Science Practices	Key	% Correct
131	3.A.4.3; 3.B.2.1	3.A.4; 3.B.2	1.4; 1.1; 1.4	A, C	66
132	3.D.2.2; 3.D.2.3	3.D.2; 3.D.2	6.4; 5.1	B, D	40
133	3.A.1.1	3.A.1	1.5; 2.2	A, D	36
134	2.B.1.1; 2.B.2.1	2.B.1; 2.B.2	2.2; 7.2; 2.2	B, D	42

Free-Response Questions

Question	Learning objectives	Essential Knowledge	Science Practices	Mean Score
1	3.A.4.3; 3.B.2.1; 4.A.2.1; 4.A.2.3; 4.A.3.2	3.A.4; 3.B.2; 4.A.2; 4.A.2; 4.A.3	1.4; 1.1; 6.4; 1.4; 2.2; 1.4	3.61
2	3.A.1.2; 4.C.1.1; 5.B.4.2; 5.D.1.4; 5.D.2.5	3.A.1; 4.C.1; 5.B.4; 5.D.1; 5.D.2	4.2; 1.4; 2.2; 1.4; 2.2; 4.2; 5.1; 6.4; 2.2	3.06
3	3.A.1.1; 3.B.3.1; 3.B.3.4; 6.A.1.2; 6.B.4.1	3.A.1; 3.B.3; 3.B.3; 6.A.1; 6.B.4	1.5; 2.1; 2.2; 6.4; 7.2; 2.2; 6.2; 1.2; 5.1; 7.2	5.24
4	2.B.1.1; 3.A.1.1; 3.A.2.1; 3.B.1.1; 3.B.1.3; 3.B.2.1	2.B.1; 3.A.1; 3.A.2; 3.B.1; 3.B.1; 3.B.2	2.2; 1.5; 2.2; 1.1; 6.4; 7.2; 1.5; 2.2; 1.1; 1.4; 2.2	1.62
5	5.B.9.3; 5.C.3.1; 5.C.3.3	5.B.9; 5.C.3; 5.C.3	2.2; 6.4; 6.4; 1.4; 2.2	2.65

AP Physics 1: Algebra-Based

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