From the 2017 Administration

AP® CollegeBoard

Physics 1: Algebra-Based

Practice Exam

Contents

Note: This publication shows the page numbers that appeared in the ***2016–17 AP Exam Instructions*** book and in the actual exam. This publication was not repaginated to begin with page 1.

Exam Instructions

The following contains instructions taken from the *2016–17 AP Exam Instructions* book.

AP® Physics 1: Algebra-Based Exam

Regularly Scheduled Exam Date: Tuesday afternoon, May 2, 2017

Late-Testing Exam Date: Thursday afernoon, May 18, 2017

AP® Physics 2: Algebra-Based Exam

Regularly Scheduled Exam Date: Wednesday afternoon, May 3, 2017

Late-Testing Exam Date: Friday morning, May 19, 2017

Section I

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

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

Section II

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

What Proctors Need to Bring to This Exam

- Exam packets
- Answer sheets
- AP Student Packs
- *2016-17 AP Coordinator's Manual*
- This book — *AP Exam Instructions*
- AP Exam Seating Chart template
- School Code and Home-School/Self-Study Codes
- Extra calculators
- Extra rulers or straightedges
- Pencil sharpener
- Container for students' electronic devices (if needed)
- Extra No. 2 pencils with erasers
- Extra pens with black or dark blue ink
- Extra paper
- Stapler
- Watch
- Signs for the door to the testing room
  - "Exam in Progress"
  - "Cell phones are prohibited in the testing room"

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 49 of the *2016-17 AP Coordinator's Manual*. See pages 46–49 of the *AP Coordinator's Manual* for more information. If a student does not have an appropriate calculator or has a graphing calculator not on the approved list, you may provide one from your supply. If the student does not want to use the calculator you provide or does not want to use a calculator at all, he or she must hand copy, date, and sign the release statement on page 47 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 325–326 for a seating chart template and instructions. See the *2016-17 AP Coordinator's Manual* for exam seating requirements (pages 51–54).

Physics 1: Algebra-Based

If you are giving the regularly scheduled exam, say:

> **It is Tuesday afternoon, May 2, and you will be taking the AP Physics 1: Algebra-Based Exam.**

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

> **It is Thursday afternoon, May 18, 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 3, and you will be taking the AP Physics 2: Algebra-Based Exam.**

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

> **It is Friday morning, May 19, and you will be taking the AP Physics 2: Algebra-Based Exam.**

> **In a moment, you will open the packet that contains your exam materials. By opening this packet, you agree to all of the AP Program's policies and procedures outlined in the *2016-17 Bulletin for AP Students and Parents*.**

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:

> **You may now remove the shrinkwrap from your exam packet and take out the Section I booklet, but do not open the booklet or the shrinkwrapped Section II materials. Put the white seals aside. . . .**
>
> **Carefully remove the AP Exam label found near the top left of your exam booklet cover. Now place it on page 1 of your answer sheet on the light blue box near the top right corner that reads "AP Exam Label."**

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

> **Read the statements on the front cover of Section I and look up when you have finished. . . .**
>
> **Sign your name and write today's date. Look up when you have finished. . . .**
>
> **Now print your full legal name where indicated. Are there any questions? . . .**
>
> **Turn to the back cover of your exam booklet and read it completely. Look up when you have finished. . . .**
>
> **Are there any questions? . . .**
>
> **You will now take the multiple-choice portion of the exam. You should have in front of you the multiple-choice booklet and your answer sheet. 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 here __________. Note Stop Time here __________. Check that students are marking their answers in pencil on their answer sheets and that they are not looking at their shrinkwrapped Section II booklets. After 1 hour and 20 minutes, say:

There are 10 minutes remaining.

After 10 minutes, say:

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

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

Now you must seal your exam booklet using the white seals you set aside earlier. Remove the white seals from the backing and press one on each area of your exam booklet cover marked "PLACE SEAL HERE." Fold each seal over the back cover. When you have finished, place the booklet on your desk, face up. I will now collect your Section I booklet. . . .

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

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

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

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

SECTION II: Free Response

After the break, say:

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

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

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

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

Read the last statement. . . .

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

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

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

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

Read Item 4. . . .

Are there any questions? . . .

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

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

Collect the Student Packs. Then say:

Are there any questions? . . .

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

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

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

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

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

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

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

> **You may begin.**

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

> **There are 10 minutes remaining.**

After 10 minutes, say:

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

If any students used extra paper for a question in the free-response section, have those students staple the extra sheet(s) to the first page corresponding to that question in their exam booklets. Complete an Incident Report. A single Incident Report may be completed for multiple students per exam subject per administration (regular or late testing) as long as all of the required information is provided. Include all exam booklets with extra sheets of paper in an Incident Report return envelope (see page 62 of the *2016-17 AP Coordinator's Manual* for complete details). Then say:

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

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

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

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

If you are giving the regularly scheduled exam, say:

You may not discuss or share 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.

Post-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.

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.

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

- Fill in the appropriate section number circle in order to access a separate AP Instructional Planning Report (for regularly scheduled exams only) or subject score roster at the class section or teacher level. See "Post-Exam Activities" in the *2016-17 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.)

AP Answer Sheet 2017

AP Number Label
(from Student Pack)

123456789

AP Exam Label
(from Section I Booklet)

CollegeBoard

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

To maintain the security of the exam and the validity of my AP score, I will allow no one else to see the multiple-choice exam content. I will seal the multiple-choice booklet when asked to do so, and I will not discuss the exam content with anyone at any time after completing the section. I am aware of and agree to the AP Program's policies and procedures as outlined in the *2016-17 Bulletin for AP Students and Parents*, including using testing accommodations (e.g., extended time, computer, etc.) only if I have been preapproved by College Board Services for Students with Disabilities.

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

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

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

C. YOUR AP NUMBER

D. EXAM DATE Month Day

E. EXAM START TIME AM PM

F. MULTIPLE-CHOICE BOOKLET SERIAL NUMBER S

G. ONLINE PROVIDER CODE

COMPLETE THIS AREA ONLY ONCE.

I. AREA CODE AND PHONE NUMBER

INTERNATIONAL PHONE

J. SCHOOL YOU ATTEND

SCHOOL CODE | School Name | City | State | Country

K. DATE OF BIRTH

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

L. SOCIAL SECURITY NUMBER (Optional)

M. COLLEGE TO RECEIVE YOUR AP SCORE REPORT

COLLEGE CODE

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

College Name | City | State | Country

N. CURRENT GRADE LEVEL

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

O. STUDENT SEARCH SERVICE®

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

Would you like us to supply your information? Yes No

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

H. AP EXAM I AM TAKING USING THIS ANSWER SHEET

Exam Name: | Form: | Form Code:

792107

SCHOOL USE ONLY

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

Fee Reduction Granted: 1 Option 1, 2 Option 2

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Q4298/1-4

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	7	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	8	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	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

ETS USE ONLY

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

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

DO NOT WRITE IN THIS AREA

QUESTIONS 76–120

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

76	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

DO NOT WRITE IN THIS AREA

COMPLETE THIS AREA ONLY ONCE.

R. YOUR MAILING ADDRESS

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

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

CITY

STATE

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

ZIP OR POSTAL CODE

COUNTRY CODE

S. FOR STUDENTS OUTSIDE THE UNITED STATES ONLY

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

Address	City	State or Province	Country	ZIP or Postal Code

T. STUDENT IDENTIFIER (Student ID Number)

U. EMAIL ADDRESS

By providing your email address, you are granting the College Board permission to use your email address in accordance with the policies in the *2016-17 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 2017 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 2017. Therefore, the timing indicated here may not be appropriate for a practice exam.

AP® Physics 1: Algebra-Based Exam

SECTION I: Multiple Choice

2017

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

At a Glance

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

Instructions

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

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

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

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

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

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

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

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

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

Form I
Form Code 4NBP4-S

83

AP® PHYSICS 1 TABLE OF INFORMATION

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

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

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

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

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

The following conventions are used in this exam.

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

AP® PHYSICS 1 EQUATIONS

MECHANICS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$L = I\omega$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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
$V = \ell wh$

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

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

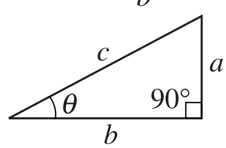
A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

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
40 Questions
Time—90 minutes

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

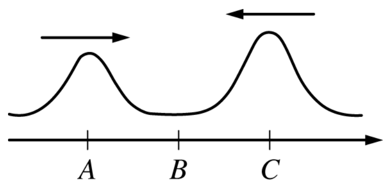
Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

1. A blue sphere and a red sphere with the same diameter are released from rest at the top of a ramp. The red sphere takes a longer time to reach the bottom of the ramp. The spheres are then rolled off a horizontal table at the same time with the same speed and fall freely to the floor. Which sphere reaches the floor first?

(A) The red sphere
(B) The blue sphere
(C) The sphere with the greater mass
(D) Neither; the spheres reach the floor at the same time.

2. A 12 kg box sliding on a horizontal floor has an initial speed of 4.0 m/s. The coefficient of friction between the box and the floor is 0.20. The box moves a distance of 4.0 m in 2.0 s. The magnitude of the change in momentum of the box during this time is most nearly

(A) $12 \text{ kg}\cdot\text{m/s}$
(B) $48 \text{ kg}\cdot\text{m/s}$
(C) $60 \text{ kg}\cdot\text{m/s}$
(D) $96 \text{ kg}\cdot\text{m/s}$



	Amplitudes		
Time t	Point A	Point B	Point C
0 s	0.2 m	0	0.3 m
0.2 s	0	x	0
0.4 s	y	0	z

3. The figure above shows two wave pulses on a spring traveling toward each other at time $t = 0$. At $t = 0.2$ s the pulses completely overlap. A student measures the amplitudes at points A, B, and C at the three times shown in the table. Which of the following is the most likely set of values that the student recorded for x, y, and z in the table?

	x	y	z
(A)	0.5 m	0.2 m	0.3 m
(B)	0.5 m	0.3 m	0.2 m
(C)	0.1 m	0.2 m	0.3 m
(D)	0.1 m	0.3 m	0.2 m

4. A rubber ball with mass 0.20 kg is dropped vertically from a height of 1.5 m above a floor. The ball bounces off of the floor, and during the bounce 0.60 J of energy is dissipated. What is the maximum height of the ball after the bounce?

   (A) 0.30 m
   (B) 0.90 m
   (C) 1.2 m
   (D) 1.5 m

5. A sled slides down a hill with friction between the sled and hill but negligible air resistance. Which of the following must be correct about the resulting change in energy of the sled-Earth system?

   (A) The sum of the kinetic energy and the gravitational potential energy changes by an amount equal to the energy dissipated by friction.
   (B) The gravitational potential energy decreases and the kinetic energy is constant.
   (C) The decrease in the gravitational potential energy is equal to the increase in kinetic energy.
   (D) The gravitational potential energy and the kinetic energy must both decrease.

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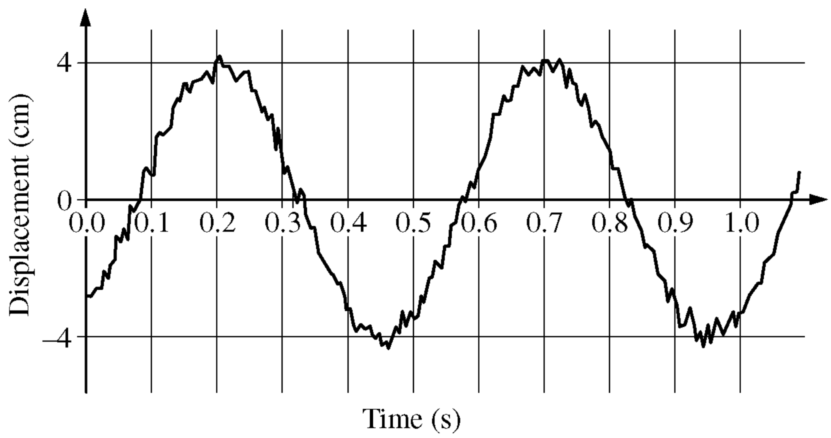
Questions 6-8 refer to the following material.



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

6. The speed of the object at time $t = 0.65$ s is most nearly equal to which of the following?

   (A) The value of the graph at 0.65 s
   (B) The slope of the line connecting the origin and the point on the graph at 0.65 s
   (C) The slope of the line connecting the point where the graph crosses the time axis near 0.57 s and the point on the graph at 0.65 s
   (D) The slope of the tangent to a best-fit sinusoidal curve at 0.65 s

7. The total distance traveled by the object between 0.35 s and 0.40 s is most nearly

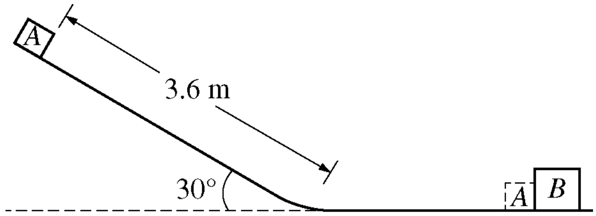
   (A) 0 cm
   (B) 2 cm
   (C) 4 cm
   (D) 6 cm

8. The frequency of oscillation is most nearly

   (A) 0.5 Hz
   (B) 0.7 Hz
   (C) 1.4 Hz
   (D) 2.0 Hz

9. An object is moving to the west at a constant speed. Three forces are exerted on the object. One force is 10 N directed due north, and another is 10 N directed due west. What is the magnitude and direction of the third force if the object is to continue moving to the west at a constant speed?

(A) $10\sqrt{3}$ N , directed northwest
(B) $10\sqrt{3}$ N , directed southeast
(C) $10\sqrt{2}$ N , directed northwest
(D) $10\sqrt{2}$ N , directed southeast



10. Block A of mass 2.0 kg is released from rest at the top of a 3.6 m long plane inclined at an angle of 30º, as shown in the figure above. After sliding on the horizontal surface, block A hits and sticks to block B, which is at rest and has mass 3.0 kg. Assume friction is negligible. The speed of the blocks after the collision is most nearly

(A) 2.4 m/s
(B) 3.2 m/s
(C) 3.8 m/s
(D) 6.0 m/s

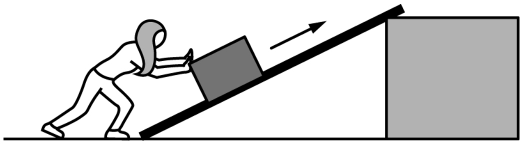


Figure 1

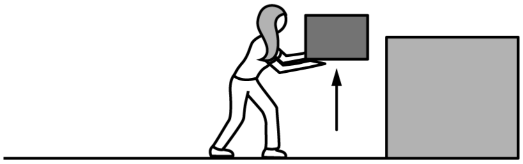
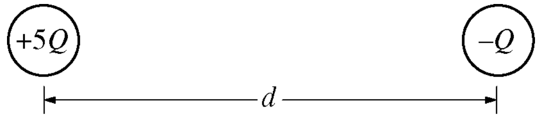


Figure 2

11. A student is asked to move a box from ground level to the top of a loading dock platform, as shown in the figures above. In Figure 1, the student pushes the box up an incline with negligible friction. In Figure 2, the student lifts the box straight up from ground level to the loading dock platform. In which case does the student do more work on the box, and why?

(A) Lifting the box straight up, because it requires a larger applied force to lift it straight up
(B) Pushing the box up the incline, because the force is applied for a longer distance
(C) Lifting the box straight up, because the incline acts as a simple machine and reduces the force required
(D) Neither method, because the work is the same in both cases, since using the ramp decreases the force by the same factor that it increases the distance



12. Two charged conducting spheres are separated by a distance d, as shown in the figure above. One sphere has charge $+5Q$, the other has charge $-Q$, and the diameter of each sphere is much smaller than d. Each sphere exerts a force of magnitude F on the other. The spheres are brought together and touch briefly. After touching, the left sphere has charge $+2Q$. The spheres are then returned to their original locations. What is the magnitude of the new force between the spheres?

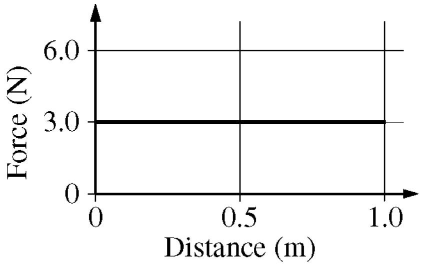
(A) $\frac{2}{5}F$
(B) $\frac{4}{5}F$
(C) $\frac{9}{5}F$
(D) $4F$

13. The wheel on a vehicle has a rotational inertia of $2.0\ \text{kg}\bullet\text{m}^2$. At the instant the wheel has a counterclockwise angular velocity of $6.0\ \text{rad/s}$, an average counterclockwise torque of $5.0\ \text{N}\bullet\text{m}$ is applied, and continues for 4.0 s. What is the <u>change</u> in angular momentum of the wheel?

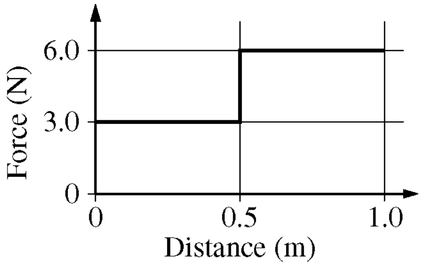
(A) $12\ \text{kg}\bullet\text{m}^2/\text{s}$
(B) $16\ \text{kg}\bullet\text{m}^2/\text{s}$
(C) $20\ \text{kg}\bullet\text{m}^2/\text{s}$
(D) $32\ \text{kg}\bullet\text{m}^2/\text{s}$

14. A student uses a spring scale to exert a horizontal force on a block, pulling the block over a smooth floor. The student repeats the procedure several times, each time pulling the block from rest through a distance of 1.0 m. For which of the following graphs of force as a function of distance will the block be moving the fastest at the end of the 1.0 m?

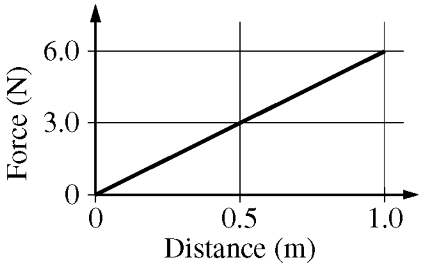
(A)



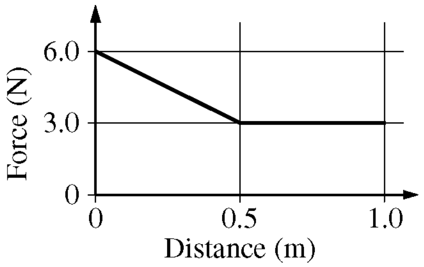
(B)



(C)



(D)

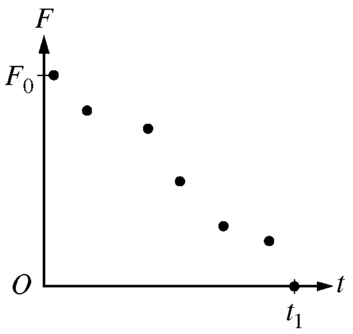


15. A projectile fired into the air explodes and splits into two halves of equal mass that hit the ground at the same time. If the projectile had not exploded, it would have landed at point X, which is a distance R to the right of the launch point. After the explosion, one of the halves lands at point Y, which is a distance $2R$ to the right of the launch point. If air resistance is negligible, where did the other half land?

(A) To the left of the launch point
(B) At the launch point
(C) Between the launch point and point X
(D) Between points X and Y

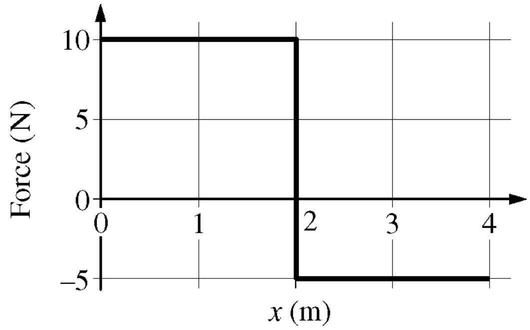
16. An elevator carrying a person of mass m is moving upward and slowing down. How does the magnitude F of the force exerted on the person by the elevator floor compare with the magnitude mg of the gravitational force?

(A) $F < mg$
(B) $F = mg$
(C) $F > mg$
(D) F can be greater than or less than mg, depending on the speed of the elevator.



17. A soft foam block of mass m slides without friction in the positive x-direction with speed v. At time $t = 0$, a student briefly pushes the block with a force probe in the positive x-direction. The graph above shows the force probe's measurements as a function of time during the push. Which of the following statements is true about the block's momentum between $t = 0$ and $t = t_1$?

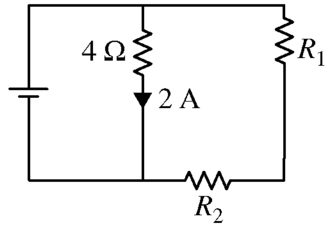
(A) The momentum of the block has decreased to zero at time t_1.
(B) The momentum of the block has increased by approximately $\frac{1}{2}F_0 t_1$.
(C) The momentum of the block has decreased by approximately $\frac{1}{2}F_0 t_1$.
(D) The change in momentum cannot be determined without knowing the distance by which the force probe compressed the block.



18. A cart is moving on a level track in the positive x-direction. A force acting parallel to the x-axis is exerted on the cart. The graph above shows the net force exerted on the cart as a function of displacement. As the cart travels from $x = 0$ m to $x = 4$ m, what is the net change in the kinetic energy of the cart?

(A) An increase of 20 J
(B) An increase of 10 J
(C) A decrease of 20 J
(D) A decrease of 10 J

Questions 19-20 refer to the following material.



In the circuit shown above, the sum of the resistances of resistors R_1 and R_2 is $16\ \Omega$.

19. What is the current in the right branch of the circuit?

(A) 0.25 A
(B) 0.50 A
(C) 1.00 A
(D) 2.00 A

20. Resistor R_1 and the $4\ \Omega$ resistor are now swapped. How does the current through the battery change, and why?

(A) The current does not change, because the resistance does not change.
(B) The current increases, because the total resistance will always decrease.
(C) The current decreases, because the total resistance will always increase.
(D) The change in current cannot be determined without knowing the resistances of R_1 and R_2.

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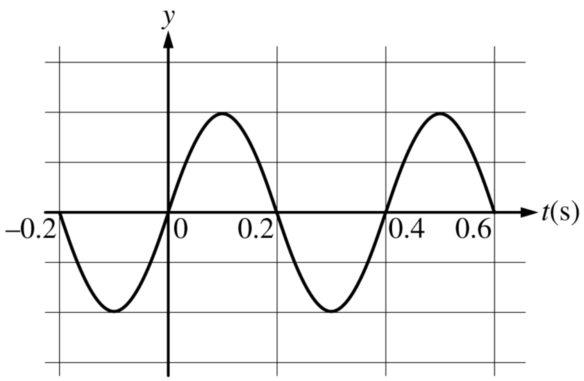
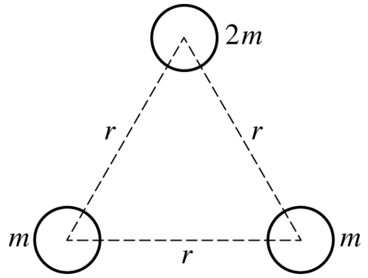


21. A transverse periodic wave travels along a string that is stretched along the x-axis. The figure above shows the y-position of a point on the string as a function of time. What further information, if any, is needed to determine the wavelength of the wave?

(A) The velocity of the wave
(B) The amplitude of the wave
(C) The frequency of the wave
(D) No further information is needed to determine the wavelength.

22. Two objects, A and B, move toward one another. Object A has twice the mass and half the speed of object B. Which of the following describes the forces the objects exert on each other when they collide and provides the best explanation?

(A) The force exerted by A on B will be twice as great as the force exerted by B on A, because A has twice the mass of B.
(B) The force exerted by A on B will be half as great as the force exerted by B on A, because A has half the speed of B.
(C) The forces exerted by each object on the other are the same, because the product of mass and speed is the same for both objects.
(D) The forces exerted by each object on the other are the same, because interacting objects cannot exert forces of different magnitude on each other.



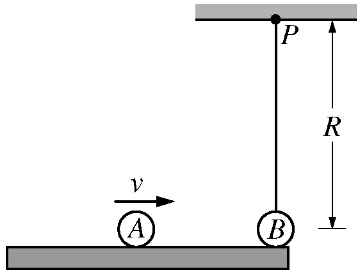
23. Three spheres, with masses indicated above, are initially far away from each other, and the gravitational potential energy of the three-sphere system is zero. The spheres are then brought together until each sphere is a distance r from the other two, as shown above. What is the new gravitational potential energy of the three-sphere system?

(A) $-\dfrac{Gm^2}{r}$

(B) $-\dfrac{2Gm^2}{r}$

(C) $-\dfrac{4Gm^2}{r}$

(D) $-\dfrac{5Gm^2}{r}$



24. Steel sphere A of mass M is moving along a horizontal surface with constant speed v. Identical steel sphere B is at rest and hangs on a string of length R attached to a support at point P, as shown in the figure above. The spheres collide, and as a result sphere A stops and sphere B swings a vertical height h before coming momentarily to rest. Knowing values for which of the following will allow determination of the angular impulse on sphere B with respect to P due to the collision?

(A) M and v only
(B) M, v, and h
(C) R and h
(D) R, M, and v

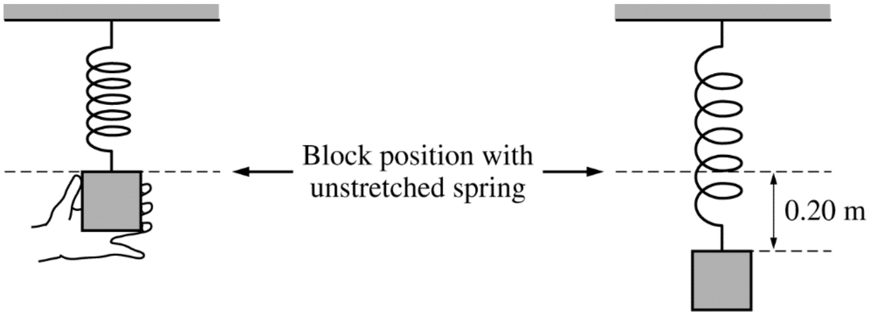
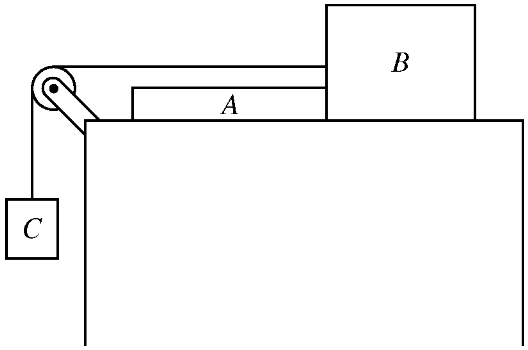


Figure 1 Figure 2

25. A 1.0 kg block is attached to an unstretched spring of spring constant 50 N/m and released from rest from the position shown in Figure 1 above. The block oscillates for a while and eventually stops moving 0.20 m below its starting point, as shown in Figure 2. What is the change in potential energy of the block-spring-Earth system between Figure 1 and Figure 2 ?

(A) -1.0 J
(B) 0 J
(C) 1.0 J
(D) 3.0 J



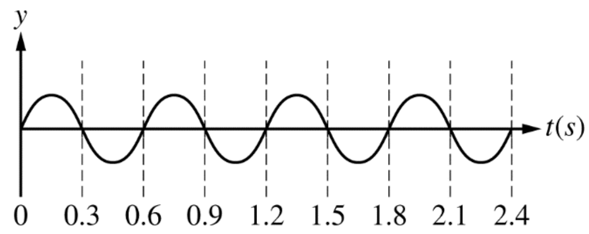
26. Blocks A and B, of masses m_A and m_B, are at rest on a frictionless surface, as shown above, with block A fixed to the table. Block C of mass m_C is suspended by a string that is tied to block B over an ideal pulley. Which of the following gives the magnitude of the force exerted by block A on block B ?

(A) $m_B g$

(B) $m_C g$

(C) $\dfrac{m_A m_C}{m_A + m_B} g$

(D) $\dfrac{m_B m_C}{m_A + m_B} g$



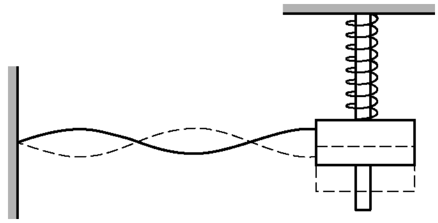
27. A student shakes a horizontally-stretched cord, creating waves. The graph above shows the vertical position y as a function of time t for a point on the cord. The student then tightens the cord so that waves on it will travel faster than before. How should the student now shake the cord to make the graph of y versus t for the point look the same as above?

(A) With fewer shakes per second than before
(B) With the same number of shakes per second as before
(C) With more shakes per second than before
(D) The answer cannot be determined without knowing the wavelength of the waves.

28. A cart of mass m is moving with negligible friction along a track with known speed v_1 to the right. It collides with and sticks to a cart of mass $4m$ moving with known speed v_2 to the right. Which of the two principles, conservation of momentum and conservation of mechanical energy, must be applied to determine the final speed of the carts, and why?

(A) Only conservation of momentum, because the momentum lost by one cart is gained by the other and there is only one unknown quantity.
(B) Both conservation of mechanical energy and conservation of momentum, because both principles apply in any collision.
(C) Both conservation of mechanical energy and conservation of momentum, because neither cart changes direction.
(D) Either conservation of momentum or conservation of mechanical energy, because only one equation is required to solve for the one unknown variable.

Questions 29-30 refer to the following material.



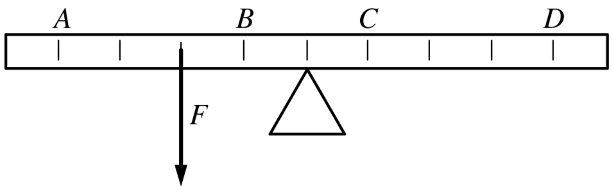
The figure above shows a pole with a spring around it and a 2.5 kg block with a hole in the middle hanging from the spring. A light horizontal cord is attached to the block and a wall. The block is oscillating at 10.0 Hz, and the standing wave shown is formed.

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

(A) 10 N/m
(B) 100 N/m
(C) $1 \times 10^3 \text{ N/m}$
(D) $1 \times 10^4 \text{ N/m}$

30. What additional measurement is needed to determine the speed of the wave on the cord?

(A) The thickness of the cord
(B) The unstretched length of the spring
(C) The average kinetic energy of the block
(D) The distance between nodes on the cord

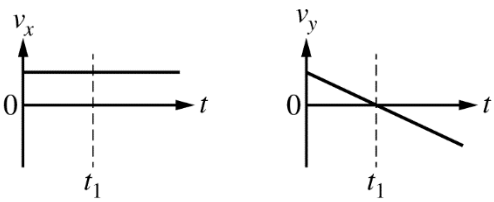


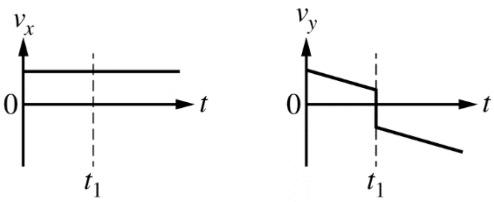
31. The figure above shows a uniform meterstick that is set on a fulcrum at its center. A force of magnitude F toward the bottom of the page is exerted on the meterstick at the position shown. At which of the labeled positions must an upward force of magnitude $2F$ be exerted on the meterstick to keep the meterstick in equilibrium?

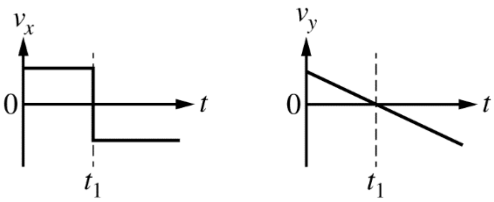
    (A) *A*
    (B) *B*
    (C) *C*
    (D) *D*

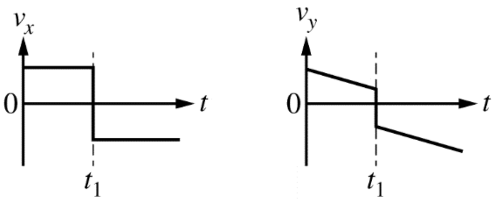
32. In a classroom at time $t = 0$, a sphere is thrown upward at a $45°$ angle to the horizontal. At time t_1, while the sphere is still rising, it bounces off the ceiling elastically and with no friction. Which of the following pairs of graphs could represent the sphere's horizontal velocity and vertical velocity as functions of time t?

    Horizontal Velocity | Vertical Velocity

    (A) 

    (B) 

    (C) 

    (D) 

GO ON TO THE NEXT PAGE.

33. Two satellites are in circular orbits around Earth. Satellite A has speed v_A. Satellite B has an orbital radius nine times that of satellite A. What is the speed of satellite B ?

(A) $v_A/9$
(B) $v_A/3$
(C) $3v_A$
(D) $9v_A$

34. In trial 1 of an experiment, a cart moves with speed v_0 on a frictionless, horizontal track and collides elastically with another cart that is initially at rest. In trial 2, the setup is identical except that the carts stick together during the collision. How does the speed of the two-cart system's center of mass change, if at all, during the collision in each trial?

	Trial 1	Trial 2
(A)	Does not change	Does not change
(B)	Does not change	Decreases
(C)	Decreases	Does not change
(D)	Decreases	Decreases

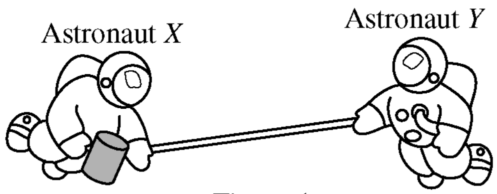


Figure 1

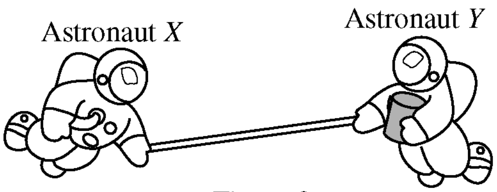
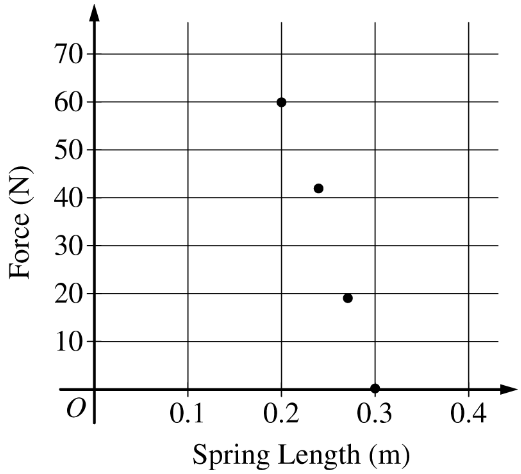


Figure 2

35. Two astronauts are connected by a taut cable and are initially at rest with respect to a nearby space station. Astronaut X throws a large container to Astronaut Y. Figure 1 above shows the astronauts immediately after the container is thrown by Astronaut X, and Figure 2 shows the astronauts immediately after the container is caught by Astronaut Y. Which of the following describes the motion of Astronaut Y in Figures 1 and 2 ?

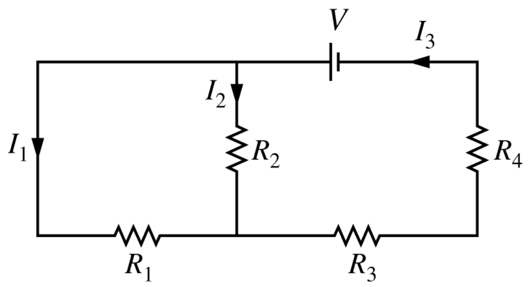
	Figure 1	Figure 2
(A)	Does not move	Moves to the right
(B)	Moves to the left	Moves to the right
(C)	Does not move	Does not move
(D)	Moves to the left	Does not move



36. The graph above shows the force exerted by a spring as a function of the length of the spring. A block on a frictionless table is pushed against the spring that is fastened to a wall. The spring is compressed until its length is 20 cm. The block is then released. Which of the following values is closest to the kinetic energy with which the block leaves the spring?

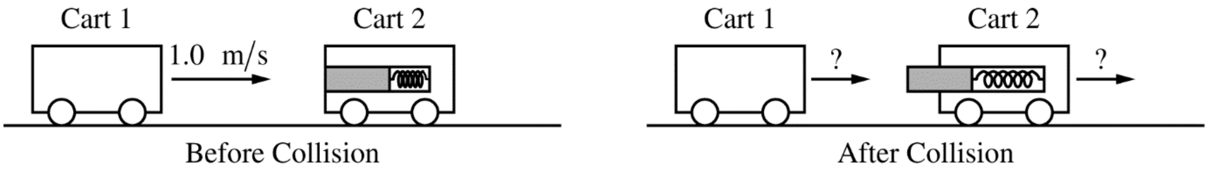
(A) 3 J
(B) 6 J
(C) 12 J
(D) 15 J

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.



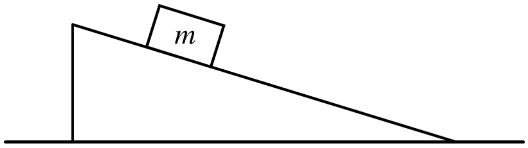
131. Which of the following equations correctly represent the total potential difference for a complete loop in the circuit diagram above? Select two answers.

(A) $V - I_1R_1 - I_3(R_3 + R_4) = 0$
(B) $V - I_1R_1 - I_2R_2 - I_3(R_3 + R_4) = 0$
(C) $V - I_3(R_3 + R_4) - I_2R_2 = 0$
(D) $V - I_1R_1 + I_2R_2 = 0$



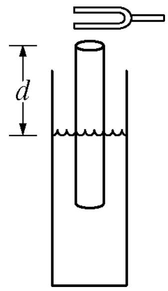
132. Two lab carts have the same mass and are free to move on a horizontal track. The carts' wheels have negligible mass. Cart 1 travels to the right at 1.0 m/s and collides with cart 2, which is initially at rest, as shown at left above. Cart 2 has a compressed spring-loaded plunger with a nonnegligible amount of stored energy. During the collision, the spring-loaded plunger pops out, staying in contact with cart 1 for 0.10 s as the spring decompresses. Negligible mechanical energy dissipates during the collision. Taking rightward as positive, the carts' velocities after the collision could be which of the following? Select two answers.

	Cart 1	Cart 2
(A)	0	1.0 m/s
(B)	0.5 m/s	0.5 m/s
(C)	-0.5 m/s	1.5 m/s
(D)	-1.0 m/s	2.0 m/s



133. A block of mass m is at rest on a rough incline, as shown in the figure above. Which of the following forces must have a magnitude equal to mg ? Select two answers.

(A) The total force exerted on the block by the incline
(B) The normal force exerted on the block by the incline
(C) The force of friction exerted on the block by the incline
(D) The gravitational force exerted on Earth by the block



134. A tuning fork is held above the opening of a pipe that is partially submerged in water, as shown in the figure above. The tuning fork is vibrating at known frequency f. Which of the following additional pieces of information, by itself, would allow the speed of sound in air to be determined? Select two answers.

(A) The shortest air column length that gives a resonance
(B) The longest air column length that gives a resonance
(C) The difference between air column lengths that give two consecutive resonances
(D) The average of the air column lengths that give two consecutive resonances

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 2017 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 **2017**

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

At a Glance

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

IMPORTANT Identification Information

PLEASE PRINT WITH PEN:

1. First two letters of your last name ☐☐
   First letter of your first name ☐
2. Date of birth
   ☐☐ Month ☐☐ Day ☐☐☐☐ Year
3. Six-digit school code
   ☐☐☐☐☐☐
4. Unless I check the box below, I grant the College Board the unlimited right to use, reproduce, and publish my free-response materials, both written and oral, for educational research and instructional purposes. My name and the name of my school will not be used in any way in connection with my free-response materials. I understand that I am free to mark "No" with no effect on my score or its reporting.
   No, I do not grant the College Board these rights. ☐

Instructions

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

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

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

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

Form I
Form Code 4NBP4-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 on 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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$L = I\omega$$

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

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

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

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

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

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

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

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

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

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

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

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

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

ELECTRICITY

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

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

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

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

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

$$R_s = \sum_i R_i$$

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

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

WAVES

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

f	=	frequency
v	=	speed
λ	=	wavelength

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

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

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

Rectangular solid
$V = \ell wh$

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

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

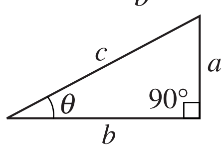
A	=	area
C	=	circumference
V	=	volume
S	=	surface area
b	=	base
h	=	height
ℓ	=	length
w	=	width
r	=	radius

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

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

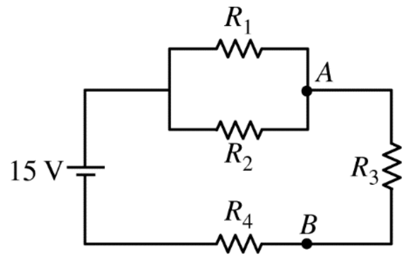
$\cos\theta = \frac{b}{c}$

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



PHYSICS 1
Section II
5 Questions
Time—90 minutes

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



1. (7 points, suggested time 13 minutes)

   A student assembles a circuit with four resistors connected to a 15 V battery, as shown above. Let I_1 be the current through resistor R_1, I_2 be the current through resistor R_2, and so on. The ranking of the resistances of the resistors is $R_4 > R_3 > R_2 > R_1$.

   (a) Rank the four currents I_1 through I_4 in order from greatest to least. If any of the currents are the same, indicate that explicitly.

   Ranking:

   Briefly explain your reasoning.

(b) The student connects a separate voltmeter across each resistor. Let ΔV_1, ΔV_2, ΔV_3, and ΔV_4 be the voltmeter readings across resistors R_1, R_2, R_3, and R_4, respectively. The student measures $\Delta V_1 = 1\text{ V}$ and $\Delta V_4 = 9\text{ V}$. Based on these measurements, determine the voltmeter readings ΔV_2 and ΔV_3.

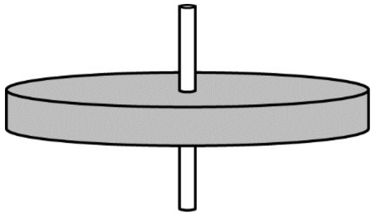
$\Delta V_2 =$ ________ $\Delta V_3 =$ ________

Briefly explain your reasoning.

(c) The student now connects a wire from point *A* to point *B*. When this wire is connected, does the current I_1 in resistor R_1 increase, decrease, or stay the same?

____ Increase ____ Decrease ____ Stay the same

Briefly explain your reasoning.



2. (12 points, suggested time 25 minutes)

A disk-shaped platform has a known rotational inertia. The platform is mounted on a fixed axle and rotates in a horizontal plane, as shown above. A student wishes to determine the frictional torque exerted on the platform by the axle as the platform rotates. The student has access to equipment that would usually be found in a school physics laboratory.

(a) Describe an experimental procedure the student could use to collect the data needed to find the frictional torque exerted on the platform while it rotates.

i. What quantities would be measured?

ii. What equipment would be used for the measurements, and how would that equipment be used?

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

GO ON TO THE NEXT PAGE.

(b) Describe how the data from the measurements could be analyzed to determine the frictional torque exerted on the rotating platform.

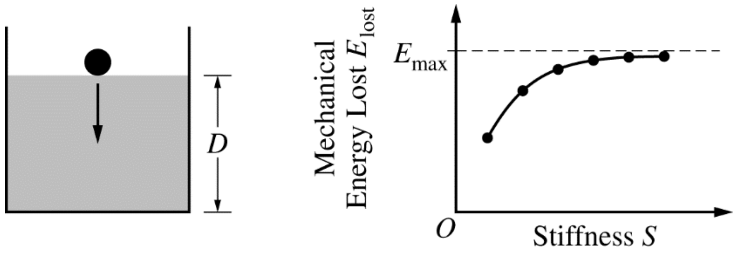
It is often assumed that the frictional force between two surfaces is independent of their relative speed. However, the details of the axle's construction are unknown, and it is possible that the frictional torque for the axle depends on the platform's angular speed.

(c) Does the experiment described in parts (a) and (b) depend on the assumption that the frictional torque is independent of the platform's angular speed?

____ Yes ____ No

Note: Either answer may be correct, depending on your experimental design.
If you answered yes, describe which part of your analysis depends on this assumption.
If you answered no, explain how your analysis does not depend on this assumption.

(d) Briefly describe how the experimental procedure described in parts (a) and (b) could be modified to determine whether the frictional torque stays constant as the angular speed changes. If no modification is necessary, state that explicitly. In either case, describe how the data could be analyzed to determine whether the frictional torque stays constant as the angular speed changes.



3. (12 points, suggested time 25 minutes)

Food scientists have created a new oil. At room temperature, the oil is a liquid. As the oil gets colder, however, it stiffens (thickens) into a sticky gel.

To explore the properties of the oil, the scientists fill a container with the oil to a height D, as shown in the figure above on the left. They drop a small steel ball of mass M from rest at the top of the oil. Using video to capture the ball's motion, the scientists calculate E_{lost}, the mechanical energy lost by the ball-Earth system from the time the ball enters the oil to the time just before the ball strikes the bottom of the container.

The scientists also define the "stiffness" S of the oil as a quantity proportional to the force required to move a rod through the oil at a standard constant speed. The scientists calculate E_{lost} and S at several different temperatures, ranging from room temperature to the lowest temperature at which the ball still falls through the oil. The graph above on the right shows E_{lost} as a function of S for the calculated data points and a best-fit curve.

(a) Give a physical reason why the curve in the graph would not reach the vertical (E_{lost}) axis even if the scientists had taken data over a broader range of temperatures.

(b) As S increases, E_{lost} approaches a maximum value labeled E_{max} on the graph above. Write an equation for E_{max} in terms of M, D, and physical constants, as appropriate.

Justify your answer.

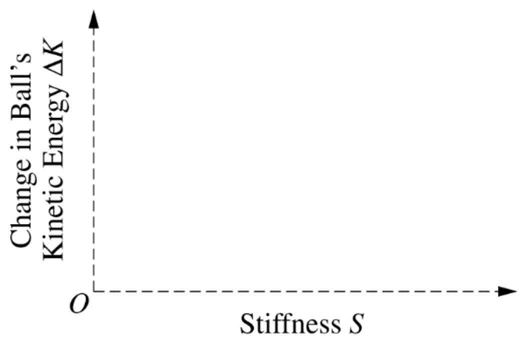
(c) One of the scientists, in trying to represent the relationship between the oil stiffness and the mechanical energy lost, writes down the equation $E_{\text{lost}} = CS^2$, where C is a constant with appropriate units. Another scientist points out that this equation cannot be correct. Give two reasons why the equation cannot be correct.

(d) Further attempting to model the ball's motion, the scientists write the following equation for the time t the ball takes to fall through the oil: $t = \frac{Z}{S}$, where Z is a constant with appropriate units. Is this equation plausible—in other words, does it make physical sense?

____ Plausible ____ Not plausible

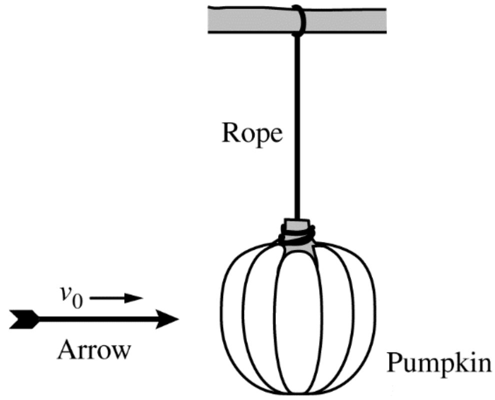
Briefly explain your reasoning.

(e) ΔK is the change in kinetic energy of the ball between the time it is released from rest and the time just before the ball strikes the bottom of the container. On the axes below, sketch ΔK as a function of S, the oil stiffness.



4. (7 points, suggested time 13 minutes)

An archer tests various arrowheads by shooting arrows at a pumpkin that is suspended from a tree branch by a rope, as shown to the right. When struck head-on by the arrow, the pumpkin swings upward on the rope. The maximum angle θ that the rope makes with the vertical is different for each arrowhead that the archer tests. Each arrow, including its arrowhead, has the same mass m and is shot with the same velocity v_0 toward the right.



The arrowheads are made of different materials, however, and each behaves differently when it strikes the pumpkin, as described below.

- *Embedded arrow*: Strikes the pumpkin and remains embedded, while the pumpkin swings to angle θ_{emb}.
- *Pass arrow*: Passes all the way through the pumpkin and continues traveling away from the archer, while the pumpkin swings to angle θ_{pass}.
- *Bounce arrow*: Bounces off the pumpkin back toward the archer, while the pumpkin swings to angle θ_{bounce}.

(a) Rank the three angles θ_{emb}, θ_{pass}, and θ_{bounce} from greatest to least in the spaces indicated below. Use “1” for the greatest angle, “2” for the next greatest, and so on. If any two or all three angles are the same, use the same number for their ranking.

_____ θ_{emb} _____ θ_{pass} _____ θ_{bounce}

(b) In a clear, coherent, paragraph-length response that may also contain figures and/or equations, justify your ranking.

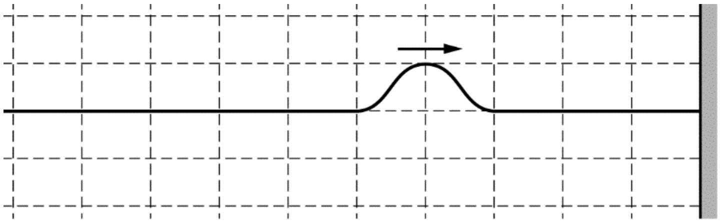


Figure 1. Pulse before reaching wall

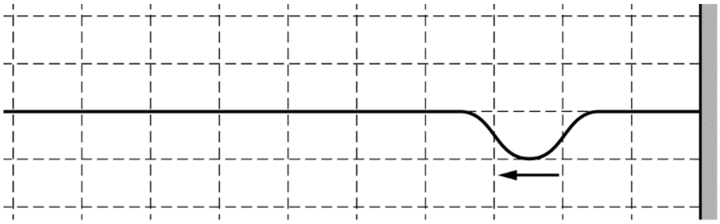
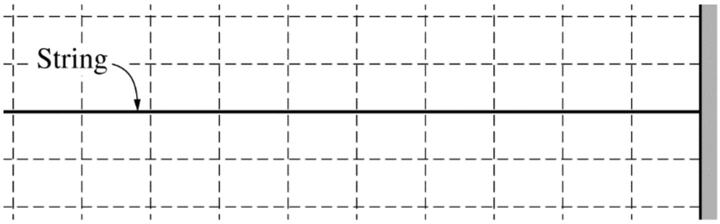


Figure 2. Pulse after reflecting from wall

5. (7 points, suggested time 13 minutes)

The right end of a long, flexible string is attached to a fixed point on a wall. The left end of the string is held by a student. The student creates a symmetric wave pulse traveling to the right, as shown in Figure 1 above. When the pulse reaches the wall, it inverts as it reflects from the wall, as shown in Figure 2 above. The figure below represents what the string looks like at the instant the peak (midpoint) of the pulse reaches the wall; at this instant the string is horizontal everywhere.



(a) At the instant shown above, does the wave pulse carry energy?

____ Yes ____ No

Briefly explain your answer.

Question 5 continues on the next page.

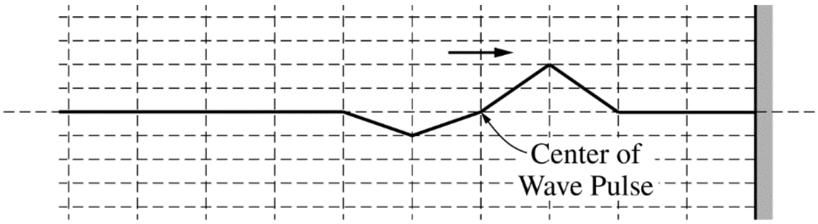
GO ON TO THE NEXT PAGE.

(b) The student then creates a second symmetric wave pulse traveling to the right on the same string. The amplitude of the second pulse is half the amplitude of the original pulse. Which pulse, if either, travels at a higher speed?

____ The higher-amplitude pulse ____ The lower-amplitude pulse ____ Neither; both pulses travel at the same speed.

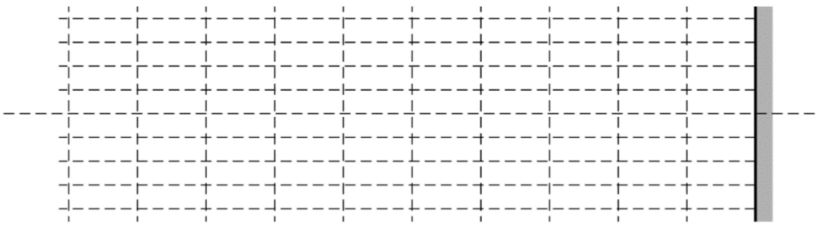
Briefly explain your reasoning.

(c) The figure below shows an idealized wave pulse traveling to the right.



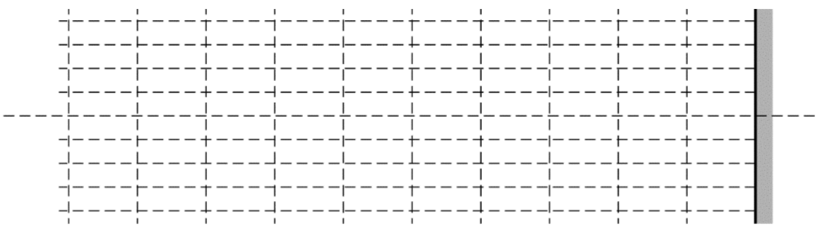
i. Consider the instant when the center of the pulse reaches the wall, which is also the instant when the right half of the pulse has reflected from the wall but the left half has not. On the grid below, sketch what the string looks like at that instant.

<u>Note:</u> Do any scratch (practice) work on the grids on the following page. You will be graded only for the sketch made on the grid below.

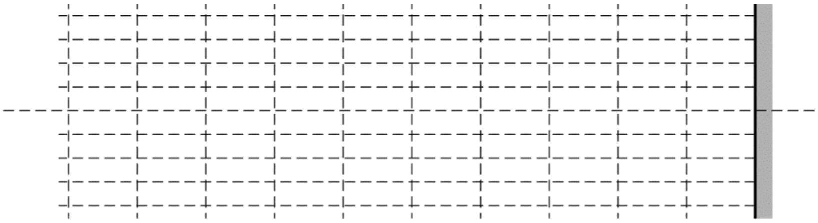


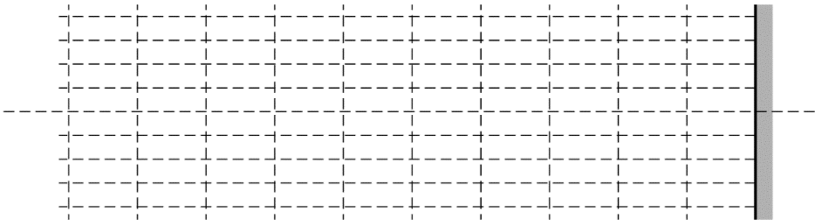
ii. Now consider an instant sometime after the entire pulse has reflected from the wall and is moving to the left. On the grid below, sketch what the string looks like at that instant.

<u>Note:</u> Do any scratch (practice) work on the grids on the following page. You will be graded only for the sketch made on the grid below.



The grids below are provided for scratch work only. Sketches made below will NOT be graded.





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

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) 4 points

For a correct ranking: — 1 point

$(I_3 = I_4) > I_1 > I_2$ or $I_3 = I_4, I_1, I_2$

Note: If an incorrect ranking is given, the explanation may still earn partial credit.

For indicating resistors in series must have the same current, and hence that $I_3 = I_4$ — 1 point

For explaining why I_1 and I_2 must be smaller than I_3 and I_4 in terms of current splitting at junctions or some other valid explanation — 1 point

For explaining why $I_1 > I_2$ in terms of unequal resistances resulting in a current split with more current through the smallest resistance, OR equal potential drops resulting in $I_1R_1 = I_2R_2$ and hence $I_1 > I_2$ — 1 point

Example: $(I_3 = I_4) > I_1 > I_2$

All the current through the battery also goes through both R_3 and R_4, and hence those two currents are the same. At the junctions to and from the parallel branch, the current "splits up" and passes through R_1 and R_2 before re-merging. So I_1 and I_2 are both less than I_3 and I_4. Because R_2 has a greater resistance than R_1, the current splits unevenly at the junction, with more current in the path with the least resistance. So the current in resistor R_1 will be greater than the current in R_2.

Question 1 (continued)

Distribution of points

(b) 2 points

Correct answer: $\Delta V_2 = 1\text{ V}$, $\Delta V_3 = 5\text{ V}$

For recognizing that resistors in parallel have the same potential difference across them, and indicating $\Delta V_2 = 1\text{ V}$ — 1 point

For applying the fact that $\Delta V = 0$ (explicitly or implicitly) for the loop containing the battery, R_1 or R_2, and both R_3 and R_4, and obtaining a value of ΔV_3 consistent with ΔV_2 (i.e. $\Delta V_2 + \Delta V_3 = 6\text{ V}$) — 1 point

Example: $\Delta V_2 = 1\text{ V}$ $\Delta V_3 = 5\text{ V}$

Since resistors R_1 and R_2 are in parallel, they have the same electric potential difference across them, so $\Delta V_2 = \Delta V_1 = 1\text{ V}$. An electron that passes through the battery, R_2, R_3, R_4, and back to the battery has competed one full loop around the circuit. Therefore, its overall potential change is $\Delta V = 0$. Therefore its potential change through the battery, of magnitude 15 V, equals the magnitude of its potential change across R_2, R_3 and R_4: $|\Delta V_2 + \Delta V_3 + \Delta V_4| = 15\text{ V}$. So $\Delta V_3 = 15\text{ V} - 9\text{ V} - 1\text{ V} = 5\text{ V}$.

(c) 1 point

Answer: "Increase"
Note: Reasoning cannot earn credit if incorrect selection is made.

For recognizing that the addition of a wire provides a path of negligible resistance around R_3 and therefore reduces the equivalent resistance of the circuit, or other valid explanation. — 1 point

Example: Adding a short circuit across R_3 gives the current a resistance-free path around R_3. This lowers the overall resistance of the circuit, increasing the current through the battery and hence through R_1.

Question 2

12 points total | **Distribution of points**

(a)

i and ii) 2 points

For indicating valid measured quantities — 1 point

Note: This point is not earned if the procedure in part (iii) includes measured quantities or measurement equipment that is not listed in parts (i) and (ii).

For a list of equipment and a plausible way to measure the quantities stated in (a)(i) — 1 point

iii) 3 points

For a practical procedure consistent with the quantities indicated in (a)(i) — 1 point

For a plausible procedure that could be used to experimentally determine frictional torque — 1 point

For including a valid method to reduce experimental uncertainty — 1 point

Example methods:

Method 1: Start the platform rotating and let it rotate freely. Use a feasible method for measuring the angular velocity at two different times.

Method 2: Apply a known external force tangential to the rim of the initially motionless platform. Measure the change in angular velocity as in method 1. Also measure the radius of the platform (or some other valid measurement of lever arm).

Method 3: Measure the torque needed to maintain the platform at a constant angular velocity. Determine if the torque is indeed constant by measuring the angular speed at two different times and seeing if they are the same within experimental uncertainty.

Method 4: With the platform freely rotating, measure angular displacement over some time interval.

(b) 3 points

For a valid expression involving the necessary angular quantity consistent with the procedure in part (a) — 1 point

For explicitly or implicitly relating the calculated quantity to angular acceleration — 1 point

For correctly combining the above two concepts in a way that would yield the frictional torque — 1 point

(c) 2 points

For correctly relating the procedure in parts (a) and (b) to the assumption of dependence or independence of frictional torque on angular speed — 1 point

For connecting the analysis to the dependence of frictional torque on angular speed — 1 point

(d) 2 points

For a modification that has any additional trial at a different angular speed OR correctly and explicitly stating that no modification is necessary — 1 point

For indicating how analysis of the initial or modified experiment could plausibly determine whether frictional torque is independent of angular speed — 1 point

Question 3

12 points total | **Distribution of points**

(a) 2 points

For indicating (explicitly or implicitly) that intersecting the vertical axis corresponds to zero stiffness — 1 point

For correctly indicating that no measurement of stiffness could be zero — 1 point

Example: The vertical axis is where $S = 0$, indicating a substance puts up no resistance to getting stirred. But even at room temperature the oil has *some* stiffness. Hence, the lowest measured stiffness is positive, not zero, and the graph reflects this.

(b) 3 points

For a correct equation: $E_{\text{max}} = MgD$ OR $E_{\text{max}} = -MgD$ — 1 point

For stating that the maximum energy that can be lost is equal to the initial energy of the system — 1 point

For stating that the initial energy of the system is the initial gravitational potential energy — 1 point

Example: The maximum energy that can be lost is equal to the initial energy, which is all gravitational potential energy: MgD.

Alternate solution for the last 2 points

For a statement or the application of mechanical energy as the sum of kinetic and potential energies — 1 point

For combining the change in the gravitational potential energy with a small change in kinetic energy as the ball falls to make a valid argument for E_{max}. — 1 point

Example: In a very stiff oil that the ball can barely fall through, it gains essentially no kinetic energy. In this case the overall change in mechanical energy, $\Delta K + \Delta U$, is approximately equal to ΔU because ΔK is essentially zero.
So, $E_{\text{max}} = |\Delta U| = MgD$.

(c) 2 points

For each of the following, up to a maximum of 2 points — 2 points

1 point for each valid, independent statement that the equation does not match the graph (maximum of 2 points).

1 point for a statement that demonstrates that E_{lost} cannot increase indefinitely.

Example statements (1 point each, any two could be combined for 2 points):

The equation indicates that E_{lost} increases indefinitely with S, but the graph has an upper limit for E_{lost}.

The equation represents a parabola (or is concave-up), which does not match the graph.

It doesn't make physical sense that E_{lost} could be more than the available potential energy MgD.

Question 3 (continued)

Distribution of points

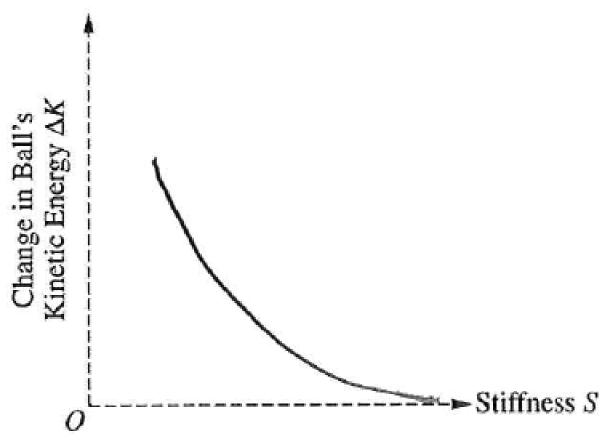
(d) 2 points

Correct answer: “Not plausible”
Note: The explanation can earn the first point if the incorrect selection is made.

For a statement or implication that the equation indicates that t increases as S decreases — 1 point
For a statement or implication that t should be larger as S increases — 1 point
Note: If only one of the above statements is written explicitly, and “Not plausible” is selected, the second point is earned by implication.

Example 1 (2 points): “Not plausible”. According to the equation, a less stiff oil makes the sphere take more time to reach the bottom.
Example 2 (2 points): “Not plausible”. A greater stiffness means that the ball should take a longer time to fall through the oil.
Example 3 (1 point): “Plausible”. The equation says that bigger S means bigger time, which agrees with the idea that a thicker oil resists the ball’s motion more.

(e) 3 points



For drawing a concave-upward curve that approaches the horizontal at higher S — 1 point
For having the maximum value of ΔK at the lowest graphed value of S, which can be $S = 0$ or a positive value — 1 point
Note: This point is not earned if the graph indicates that ΔK approaches infinity as S approaches zero.
For high values of S, the graph approaches and does not cross the horizontal axis — 1 point
Note: This point is earned if the graph touches the horizontal axis without crossing it.

Question 4

7 points total | **Distribution of points**

(a)

Correct answer: __2__ θ_{embed} __3__ θ_{pass} __1__ θ_{bounce}

(b) 7 points

For using conservation of momentum Note: This point is earned for an indication of how momentum conservation applies to the situation.	1 point
For correctly stating or implying that in all three cases the magnitude of the change in the horizontal momentum of the arrow during the collision equals magnitude of the momentum gained by the pumpkin	1 point
For a valid argument explaining why the Bounce arrow must transfer the most momentum	1 point
For stating that the Pass arrow ends up faster than the Embedded arrow or does not transfer as much momentum to the pumpkin immediately after collision	1 point
For indicating (regardless of conclusion about whether the Pass or Embedded arrow ends up going faster after the collision) that the arrow that slowed more during the collision transfers more momentum to the pumpkin	1 point
For an explicit or implicit correct justification, in terms of energy conservation, that the angle reached by the pumpkin is related to the speed of the pumpkin just after the collision	1 point
For a logical, relevant, and internally consistent response that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response	1 point

Example: The Bounce arrow is the only one that reverses direction, so has momentum to the left after the collision. By conservation of momentum the pumpkin must then have a greater momentum to the right than the arrow had before the collision. After the Embedded arrow hits, the arrow and pumpkin together have the same momentum as the arrow did just before the collision. The Pass arrow still has some momentum to the right after hitting the pumpkin so by conservation of momentum the pumpkin has less momentum to the right than the arrow did before the collision. By conservation of energy, the maximum angle that the pumpkin reaches depends on the speed of the pumpkin (higher speed means higher angle), so the Bounce arrow pumpkin has the highest angle and the Pass arrow pumpkin has the lowest angle.

Question 5

7 points total | **Distribution of points**

(a) 1 point

Answer: “Yes”
Explanation cannot earn credit if “No” is selected.

For a statement of conservation of energy, or explicit reference to the motion or kinetic energy of the string at the moment shown in the diagram — 1 point

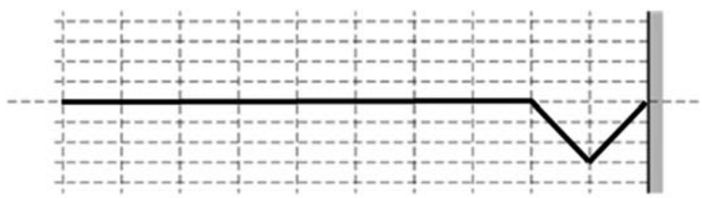
(b) 1 point

Correct Answer: “Neither”
Explanation cannot earn credit if either of the other choices are selected.

For an explanation that both pulses travel at the same speed because wave speed is a property of the string, which does not change — 1 point

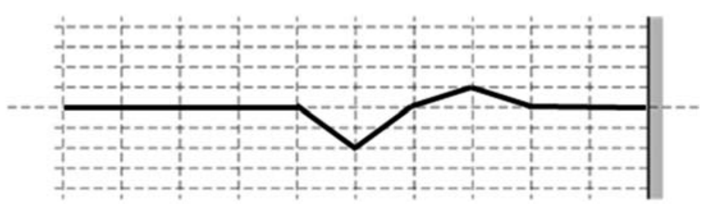
(c)

i) 3 points



For drawing the entire wave pulse below the equilibrium position of the string — 1 point
For drawing a wave pulse with amplitude of -3 units — 1 point
Note: This point is not earned if the equilibrium position or left-most portion of the pulse is drawn or indicated at the incorrect height.
For a pulse with symmetric triangular shape that is 2 units wide and located in the rightmost 2 units of the grid, and no other nonzero portions of the string — 1 point
Note: The portion of the string with zero displacement need not be sketched.

ii) 2 points



For a pulse that is a vertical inversion of the original pulse (i.e. 2 unit portion going down and 1 unit portion going up) — 1 point
For a pulse that is a horizontal inversion of the original pulse (i.e. 2 unit portion on the left and 1 unit portion on the right) — 1 point
Note: The portion of the string with zero displacement need not be sketched.

Scoring Worksheet

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

2017 AP Physics 1 Scoring Worksheet

Section I: Multiple Choice

____________ × 1.0000 = ________________
Number Correct (out of 40) — Weighted Section I Score (Do not round)

Section II: Free Response

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

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

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

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

Question 5 ________ × 0.8888 = ________
(out of 7) (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
55-80	5
42-54	4
32-41	3
20-31	2
0-19	1

Question Descriptors and Performance Data

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

2017 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.1.1; 4.A.2.1	3.A.1; 4.A.2	1.5; 2.2; 6.4	D	74
2	3.A.1.1; 3.B.2.1; 4.B.2.1	3.A.1; 3.B.2; 4.B.2	1.5; 2.2; 1.1; 1.4; 2.2; 2.2	B	62
3	6.D.1.1; 6.D.1.2	6.D.1	1.4; 5.1	B	70
4	4.C.1.1	4.C.1	1.4; 2.2	C	66
5	5.B.5.4	5.B.5	6.4; 7.2	A	58
6	3.A.1.1; 3.A.1.3; 3.B.3.3	3.A.1; 3.B.3	1.5; 2.2; 5.1; 2.2; 5.1	D	49
7	3.A.1.1; 3.A.1.3	3.A.1	1.5; 2.2; 5.1	B	78
8	3.B.3.3	3.B.3	2.2; 5.1	D	55
9	3.A.3.1; 3.B.1.3	3.A.3; 3.B.1	6.4; 1.5; 2.2	D	55
10	5.D.2.5	5.D.2	2.2	A	48
11	5.B.5.5	5.B.5	2.2; 6.4	D	51
12	1.B.1.1; 3.C.2.1	1.B.1; 3.C.2	6.4; 6.4	B	41
13	4.D.3.1	4.D.3	2.2	C	61
14	5.B.5.3	5.B.5	1.4; 2.2	B	49
15	5.D.3.1	5.D.3	6.4	B	38
16	2.B.1.1; 3.B.1.1; 3.B.2.1	2.B.1; 3.B.1; 3.B.2	2.2; 6.4; 1.1; 1.4; 2.2	A	38
17	4.B.2.2	4.B.2	5.1	B	37
18	3.E.1.3; 3.E.1.4; 4.C.2.1	3.E.1; 4.C.2	1.4; 2.2; 2.2; 6.4	B	40
19	5.B.9.3; 5.C.3.3	5.B.9; 5.C.3	2.2; 1.4; 2.2	B	49
20	5.C.3.1	5.C.3	6.4; 7.2	D	49
21	6.B.2.1	6.B.2	1.4	A	46
22	3.A.4.1	3.A.4	1.4; 6.2	D	44
23	4.C.1.1; 5.B.3.2	4.C.1; 5.B.3	1.4; 2.2; 1.4; 2.2	D	16
24	3.F.3.1	3.F.3	6.4; 7.2	D	40
25	5.B.3.3	5.B.3	1.4	A	28
26	3.B.1.3; 3.B.2.1	3.B.1; 3.B.2	1.5; 2.2; 1.1; 1.4; 2.2	B	48
27	6.B.1.1	6.B.1	1.4; 2.2	B	11
28	5.D.2.5	5.D.2	2.1	A	48
29	3.B.3.3	3.B.3	2.2	D	21
30	6.D.3.2; 6.D.4.2	6.D.3; 6.D.4	6.4; 2.2	D	69
31	3.F.1.1	3.F.1	1.4	B	27
32	3.A.1.1; 3.B.1.1	3.A.1; 3.B.1	1.5; 2.2; 6.4	B	46
33	3.C.1.2	3.C.1	2.2	B	27
34	4.A.1.1; 5.D.1.1; 5.D.2.1	4.A.1; 5.D.1; 5.D.2	1.2; 6.4; 6.4; 7.2	A	24
35	4.A.1.1	4.A.1	1.2; 1.4; 6.4	D	24
36	4.C.2.1; 5.B.5.5	4.C.2; 5.B.5	6.4; 2.2; 6.4	A	23

2017 AP Physics 1: Algebra-Based
Question Descriptors and Performance Data

Question	Learning Objectives	Essential Knowledge	Science Practices	Key	% Correct
131	5.B.9.3	5.B.9	2.2	A,C	42
132	5.D.1.2	5.D.1	5.1; 5.3	C,D	43
133	3.A.3.1; 3.A.3.3; 3.A.4.2; 3.A.4.3	3.A.3; 3.A.4	6.4; 7.2; 1.4; 6.4; 7.2; 1.4	A,D	36
134	6.D.1.2	6.D.1	4.2	A,C	32

Free-Response Questions

Question	Learning Objectives	Essential Knowledge	Science Practices	Mean Score
1	5.B.9.3; 5.C.3.1; 5.C.3.3	5.B.9; 5.C.3	2.2; 6.4; 6.4; 1.4; 2.2	2.62
2	3.A.1.2; 3.A.1.3; 3.F.2.2; 3.F.3.3; 4.D.3.2	3.A.1; 3.F.2; 3.F.3; 4.D.3	4.2; 5.1; 4.1; 4.2; 5.1; 4.1; 4.2; 5.1; 4.1; 4.2	3.08
3	2.B.1.1; 3.A.1.1; 3.A.3.1; 3.B.1.1; 3.C.4.1; 4.C.1.1; 4.C.1.2; 4.C.2.1; 5.B.1.2; 5.B.3.1; 5.B.4.1; 5.B.4.2; 5.B.5.1; 5.B.5.4	2.B.1; 3.A.1; 3.A.3; 3.B.1; 3.C.1; 3.C.4; 4.C.1; 4.C.2; 5.B.1; 5.B.3; 5.B.4; 5.B.5	2.2; 7.2; 1.5; 2.2; 6.4; 6.4; 7.2; 6.1; 1.4; 2.1; 2.2; 6.4; 6.4; 1.5; 2.2; 6.4; 7.2; 6.4; 7.2; 1.4; 2.1; 2.2; 5.1; 6.4; 7.2	4.25
4	3.A.1.1; 3.A.4.1; 3.A.4.2; 3.B.1.1; 5.B.3.1; 5.B.3.3; 5.B.4.1; 5.B.4.2; 5.D.1.5; 5.D.2.1; 5.D.2.5	1.A.1; 3.A.1; 3.A.4; 3.B.1; 5.B.3; 5.B.4; 5.D.1; 5.D.2	1.5; 1.4; 6.2; 6.4; 6.4; 2.2; 6.4; 1.4; 2.2; 6.4; 1.4; 2.2; 2.2; 6.4; 2.1; 2.2	1.13
5	5.B.4.1; 6.A.1.2; 6.D.1.1	5.B.4; 6.A.1; 6.D.1	6.4; 7.2; 1.2; 1.1; 1.4	3.57

AP Physics 1: Algebra-Based

The College Board

The College Board is a mission-driven not-for-profit organization that connects students to college success and opportunity. Founded in 1900, the College Board was created to expand access to higher education. Today, the membership association is made up of over 6,000 of the world's leading educational institutions and is dedicated to promoting excellence and equity in education. Each year, the College Board helps more than seven million students prepare for a successful transition to college through programs and services in college readiness and college success — including the SAT® and the Advanced Placement Program®. The organization also serves the education community through research and advocacy on behalf of students, educators, and schools. The College Board is committed to the principles of excellence and equity, and that commitment is embodied in all of its programs, services, activities, and concerns.