CollegeBoard

AP® Physics C: Mechanics Practice Exam

From the 2014 Administration

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Contents

Exam Instructions

Student Answer Sheet for the Multiple-Choice Section

Section I: Multiple-Choice Questions

Section II: Free-Response Questions

Multiple-Choice Answer Key

Free-Response Scoring Guidelines

Scoring Worksheet

Note: This publication shows the page numbers that appeared in the *2013–14 AP Exam Instructions* book and in the actual exam. This publication was not repaginated to begin with page 1.

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Exam Instructions

The following contains instructions taken from the *2013–14 AP Exam Instructions* book.

AP® Physics C: Mechanics Exam

Regularly Scheduled Exam Date: Monday afternoon, May 12, 2014

Late-Testing Exam Date: Friday afternoon, May 23, 2014

Section I Total Time: 45 min. Section II Total Time: 45 min.

What Proctors Need to Bring to This Exam

- Exam packets
- Answer sheets
- AP Student Packs
- *2013-14 AP Coordinator's Manual*
- This book — *AP Exam Instructions*
- School Code and Home-School/Self-Study Codes
- Extra calculators
- Extra rulers or straightedges
- Pencil sharpener
- Extra No. 2 pencils with erasers
- Extra pens with black or dark blue ink
- Extra paper
- Stapler
- Watch
- Signs for the door to the testing room
  - "Exam in Progress"
  - "Cell phones are prohibited in the testing room"

Students are permitted to use four-function, scientific, or graphing calculators to answer the questions in Section II of the AP Physics C: Mechanics Exam. Students are not allowed to use calculators in Section I. 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 45 of the *2013-14 AP Coordinator's Manual*. See pages 42–45 of the *2013-14 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 43 of the *2013-14 AP Coordinator's Manual*.

During the administration of Section II, 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.**

Rulers and straightedges may be used for the entire exam.

Students may take both Physics C exams, Mechanics only, or Electricity and Magnetism only. The Mechanics exam is administered first, after which students taking both exams are given a break. Then the Electricity and Magnetism exam is administered. Prior to testing day, determine which exams students are taking. Those taking both Physics C exams and those taking Physics C: Mechanics only should report for the 12 noon start time (11 a.m. in Alaska). Those taking Electricity and Magnetism only should report to the testing room after the break (approximately 2 p.m., 1 p.m. in Alaska). If all students are taking Electricity and Magnetism only, you must not begin the exam before 2 p.m.

The two exams are in separate exam packets, and require separate answer sheets. At the beginning of the session, you will distribute **only** the packets and answer sheets for Mechanics. The materials for Electricity and Magnetism will be distributed after the break.

SECTION I: Multiple Choice

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

This exam includes survey questions. The time allowed for the survey questions is in addition to the actual test-taking time.

Make sure that you begin the exam at the designated time.

If you are giving the regularly scheduled exam, say:

It is Monday afternoon, May 12, and you will be taking the AP Physics C: Mechanics Exam.

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

It is Friday afternoon, May 23, and you will be taking the AP Physics C: Mechanics 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 *2013-14 Bulletin for AP Students and Parents*. You may now remove the shrinkwrap from your exam packet and take out the Section I booklet, but do not open the booklet or the shrinkwrapped Section II materials. Put the white seals aside. . . .

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

If students accidentally place the exam label in the space for the number label or vice versa, advise them to leave the labels in place. They should not try to remove the label; their exam will 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 and read it completely. Look up when you have finished. . . .

Are there any questions? . . .

Section I is the multiple-choice portion of the exam. You may never discuss these specific multiple-choice questions at any time in any form with anyone, including your teacher and other students. If you disclose these questions through any means, your AP Exam score will be canceled. Are there any questions? . . .

You must complete the answer sheet using a No. 2 pencil only. Mark all of your responses beginning on page 2 of your answer sheet, one response per 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 and straightedges may be used for the entire exam, but calculators are not allowed for Section I. Please put all of your calculators under your chair. Are there any questions? . . .

You have 45 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 45 minutes, say:

Stop working and turn to the last page in your booklet. . . .

You have 2 minutes to answer Questions 101–106. These are survey questions and will not affect your score. You may not go back to work on any of the exam questions. You may now begin.

To help you and your proctors make sure students are not working on the exam questions, the two pages with the survey questions are identified with a large S on the upper corner of each page. Give students 2 minutes to answer the survey questions. Then say:

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. I will now collect your answer sheet.

Collect an answer sheet from each student. Check that each answer sheet has an AP number label and an AP Exam label. Then say:

Now you must seal your exam booklet. 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. . . .

SECTION II: Free Response

Check that each student has signed the front cover of the sealed Section I booklet. When all Section I materials have been collected and accounted for, 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 place an AP number label on the shaded box. If you don't have any AP number labels, write your AP number in the box. Look up when you have finished. . . .

Read the last statement. . . .

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

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

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

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

Read Item 4. . . .

Are there any questions? . . .

I need to collect the Student Pack from anyone who will be taking another AP Exam. Keep it, however, if you will be taking the Physics C: Electricity and Magnetism exam this afternoon. If you have no other AP Exams to take, place your Student Pack under your chair now. . . .

While Student Packs are being collected, 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? . . .

Calculators may be used for Section II. You may get your calculators from under your chair and place them on your desk. . . .

You have 45 minutes to complete Section II. You are responsible for pacing yourself, and may proceed freely from one question to the next. 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 piece of paper you use, be sure to write only your AP number and the number of the question you are working on. Do not write your name. Are there any questions? . . .

You may begin.

Note Start Time here _____. Note Stop Time here _____. Check that students are writing their answers in their exam booklets. You should also make sure that Hewlett-Packard calculators' infrared ports are not facing each other and that students are not sharing calculators. After 35 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 the free-response section, have those students staple the extra sheet/s to the first page corresponding to that question in their exam booklets. 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 who are taking Mechanics only any electronic devices you may have collected before the start of the exam.

If you are giving the regularly scheduled exam, say:

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

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

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

If any students completed the AP number card at the beginning of this exam, and are about to be dismissed, 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.

If no students are taking Physics C: Electricity and Magnetism, say:

You are now dismissed.

If some students are taking Physics C: Electricity and Magnetism, say:

Those of you taking Mechanics only are now dismissed.

The students taking the Electricity and Magnetism exam now get a 10-minute break. Remember that the Electricity and Magnetism exam cannot begin before 2 p.m., but should start before 3 p.m. After the students taking Mechanics only have left, say:

If you will also be taking the Physics C: Electricity and Magnetism exam, 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 everything you placed under your chair at the beginning of the exam must stay there. You are not allowed to consult teachers, other students, or textbooks about the exam 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. If you do not follow these rules, your score could be canceled. Are there any questions? . . .

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

If you will be administering Physics C: Electricity and Magnetism exam at 2 p.m., be sure all exam materials are kept secure during the break. When the students return from break, turn to page 200 and begin the exam administration for Physics C: Electricity and Magnetism.

If you have no students taking Physics C: Electricity and Magnetism, all exam materials should be put 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 *2013-14 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 2014

AP Number Label
(from Student Pack)

B123456789T

AP Exam Label
(from Section I Booklet)

CollegeBoard

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

To maintain the security of the exam and the validity of my AP score, I will allow no one else to see the multiple-choice questions. I will seal the multiple-choice booklet when asked to do so, and I will not discuss these questions with anyone at any time after completing the section. I am aware of and agree to the AP Program's policies and procedures as outlined in the *2013-14 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

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

773898

SCHOOL USE ONLY

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

Fee Reduction Granted: 1 Option 1 2 Option 2

99735-00657• UNLWEB114

Q3779/1-4

COMPLETE THIS AREA AT EACH EXAM (IF APPLICABLE)

O. 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)

P. 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. 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)

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

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

ETS USE ONLY

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

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

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DO NOT WRITE IN THIS AREA

COMPLETE THIS AREA ONLY ONCE.

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

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

CITY

ZIP OR POSTAL CODE

COUNTRY CODE

STATE

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

R. FOR STUDENTS OUTSIDE THE UNITED STATES ONLY If your address does not fit in the spaces provided in Item Q, fill in as many circles as you can, then fill in the circle in Item R and print the remainder of your address in the spaces provided.

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

T. EMAIL ADDRESS By providing your email address, you are granting the College Board permission to use your email in accordance with the policies in the *2013-14 Bulletin for AP Students and Parents*.

S. STUDENT IDENTIFIER (Student ID Number)

U. 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.

V. SEX

◯ Female ◯ Male

W. WHICH LANGUAGE DO YOU KNOW BEST?

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

X. ETHNICITY/RACE

◯ American Indian or Alaska Native
◯ Asian, Asian American or Pacific Islander
◯ Black or African American
◯ Mexican or Mexican American
◯ Puerto Rican
◯ Other Hispanic, Latino or Latin American
◯ White
◯ Other

Y. PARENTAL EDUCATION LEVEL

Father/ Male Guardian	Mother/ Female Guardian	
◯	◯	Grade school
◯	◯	Some high school
◯	◯	High school diploma or equivalent
◯	◯	Business 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 2014 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.)

PLACE SEAL HERE

AP® Physics C: Mechanics Exam

SECTION I: Multiple Choice

2014

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

At a Glance

Total Time
45 minutes
Number of Questions
35
Percent of Total Score
50%
Writing Instrument
Pencil required
Electronic Device
None allowed

Instructions

Section I of this exam contains 35 multiple-choice questions. For these questions, fill in only the circles for numbers 1 through 35 on your answer sheet. A table of information that may be helpful is in the booklet. 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. After you have decided which of the suggested answers is best, completely fill in the corresponding circle on the answer sheet. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely. Here is a sample question and answer.

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

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 the multiple-choice section is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

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Form I
Form Code 4JBP6-S

80

PLACE SEAL HERE
DO NOT seal answer sheet inside

TABLE OF INFORMATION, EFFECTIVE 2012

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	1 electron volt, $1 \text{ eV} = 1.60 \times 10^{-19}$ J
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Speed of light, $c = 3.00 \times 10^{8}$ m/s
Avogadro's number, $N_0 = 6.02 \times 10^{23}$ mol^{-1}	Universal gravitational constant, $G = 6.67 \times 10^{-11}$ m^3/kg·s^2
Universal gas constant, $R = 8.31$ J/(mol·K)	Acceleration due to gravity at Earth's surface, $g = 9.8$ m/s^2
Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K	

1 unified atomic mass unit,	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg} = 931 \text{ MeV}/c^2$
Planck's constant,	$h = 6.63 \times 10^{-34}$ J·s $= 4.14 \times 10^{-15}$ eV·s
	$hc = 1.99 \times 10^{-25}$ J·m $= 1.24 \times 10^{3}$ eV·nm
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}$ C^2/N·m^2
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9}$ N·m^2/C^2
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ (T·m)/A
Magnetic constant,	$k' = \mu_0/4\pi = 1 \times 10^{-7}$ (T·m)/A
1 atmosphere pressure,	$1 \text{ atm} = 1.0 \times 10^{5}$ N/m^2 $= 1.0 \times 10^{5}$ Pa

UNIT SYMBOLS								
	meter,	m	mole,	mol	watt,	W	farad,	F
	kilogram,	kg	hertz,	Hz	coulomb,	C	tesla,	T
	second,	s	newton,	N	volt,	V	degree Celsius,	°C
	ampere,	A	pascal,	Pa	ohm,	Ω	electron-volt,	eV
	kelvin,	K	joule,	J	henry,	H		

PREFIXES		
Factor	Prefix	Symbol
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. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.

II. The direction of any electric current is the direction of flow of positive charge (conventional current).

III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

PHYSICS C: MECHANICS
SECTION I
Time—45 minutes
35 Questions

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

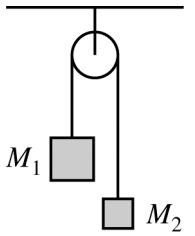
Note: To simplify calculations, you may use $g = 10\,\text{m/s}^2$ in all problems.

1. An object is released from rest from a great height and reaches its terminal velocity. Which of the following statements is true of the object while it is falling with terminal velocity?

   (A) There is no longer a gravitational force on it.
   (B) There is no longer a drag (air resistance) force on it.
   (C) Its acceleration is upward.
   (D) The magnitudes of the gravitational and drag forces on it are equal.
   (E) The gravitational and drag forces on it act in the same direction.

2. A student with a mass of 50 kg is standing on a bathroom scale while riding in an elevator. If the reading on the scale is 400 N, which of the following is a correct description of the elevator's motion?

   (A) Moving upward with increasing speed
   (B) Moving upward with constant speed
   (C) Moving downward with constant speed
   (D) Moving downward with increasing speed
   (E) Moving downward with decreasing speed



3. The system represented above consists of two objects of unequal masses, M_1 and M_2, with $M_1 > M_2$. The objects hang from the ends of a cord of negligible mass that passes over a pulley with negligible mass and friction. Which of the following is true about the changes in the gravitational potential energy, ΔU, and kinetic energy, ΔK, of the system soon after the objects are released from rest?

   (A) $\Delta U < 0$ and $\Delta K > 0$
   (B) $\Delta U = 0$ and $\Delta K > 0$
   (C) $\Delta U < 0$ and $\Delta K = 0$
   (D) $\Delta U = 0$ and $\Delta K = 0$
   (E) $\Delta U > 0$ and $\Delta K < 0$

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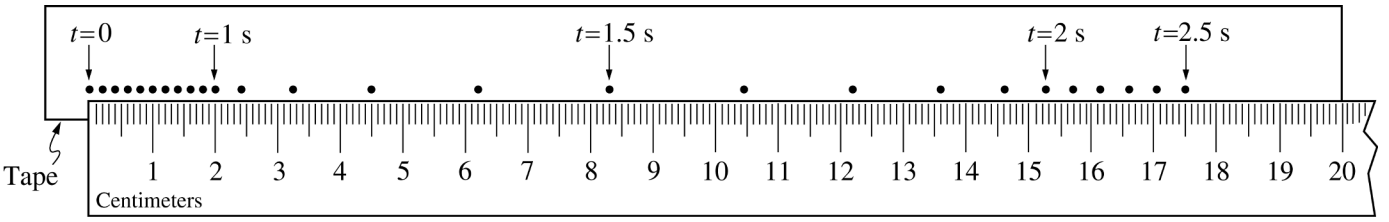
Questions 4-6

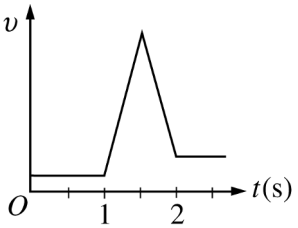
A tape attached to a moving object was pulled by the object through a marker that put dots on the tape at a constant rate of 10 dots per second for a period of 2.5 s. The figure below shows the marked tape next to a centimeter ruler.

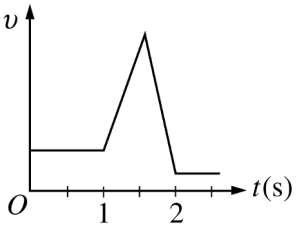


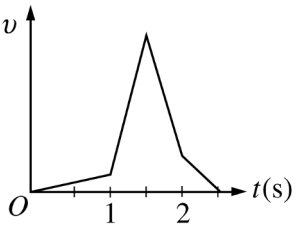
4. The average speed of the object for the total time recorded on the tape is most nearly

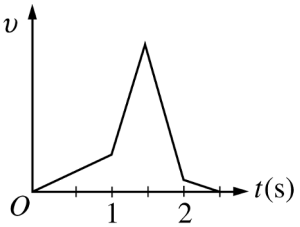
(A) 2.0 cm/s
(B) 3.3 cm/s
(C) 4.5 cm/s
(D) 5.5 cm/s
(E) 7.0 cm/s

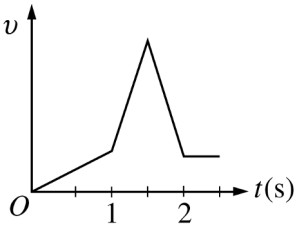
5. Which of the following best represents the graph of the velocity of the object versus time?

(A)


(B)


(C)


(D)


(E)


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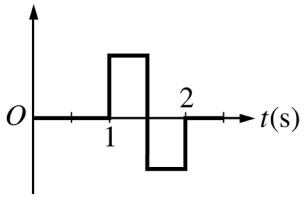
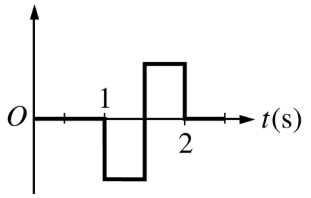
6. Which of the following best represents the graph of the acceleration of the object versus time?

(A)


(B)


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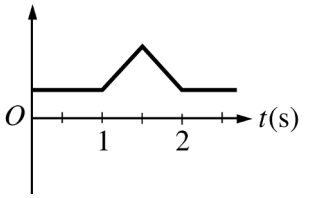

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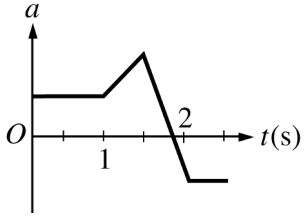

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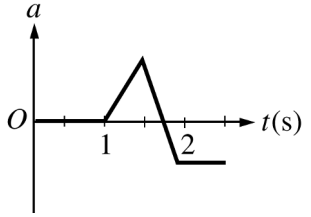

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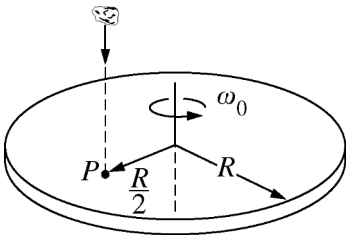
Questions 7-8



A turntable with mass m, radius R, and rotational inertia $\frac{mR^2}{2}$ initially rotates freely about an axis through its center at constant angular speed with negligible friction. A piece of clay, also of mass m, falls vertically onto the turntable, as shown above, and sticks to it at point P, a distance $\frac{R}{2}$ from the center of rotation.

7. What is the rotational inertia of the clay-turntable system after the collision?

(A) $\frac{1}{4}mR^2$

(B) $\frac{1}{2}mR^2$

(C) $\frac{3}{4}mR^2$

(D) mR^2

(E) $2mR^2$

8. What happens to the rotational speed of the turntable and the angular momentum of the clay-turntable system about the axis as a result of the collision?

	Rotational Speed	Angular Momentum
(A)	Stays the same	Increases
(B)	Stays the same	Stays the same
(C)	Stays the same	Decreases
(D)	Decreases	Stays the same
(E)	Decreases	Decreases

9. Which of the following must be true in order for a rotating platform to continue rotating with a constant angular velocity?

(A) There are no forces exerted on it.
(B) There is no friction exerted on it.
(C) There is zero net force exerted on it.
(D) There are no torques exerted on it.
(E) There is zero net torque exerted on it.

10. A newly discovered planet is found to have twice the radius and three times the mass of Earth. If the acceleration due to gravity at the surface of Earth is g, the acceleration due to gravity at the surface of the new planet is

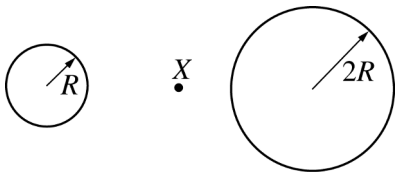
(A) $\frac{2g}{3}$

(B) $\frac{3g}{4}$

(C) g

(D) $\frac{4g}{3}$

(E) $\frac{3g}{2}$



11. At point X shown above, which is midway between the centers of two isolated planets of radii R and $2R$, the net gravitational force on an object is zero. If the mass of the smaller planet is M, the mass of the larger planet is

(A) $\frac{M}{4}$

(B) $\frac{M}{2}$

(C) M

(D) $2M$

(E) $4M$

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12. A particle moves along a straight line. Its speed in m/s is given by $v = a + bt^2$, where a and b are constants and t is time in seconds. How far does the particle move between $t = 1$ s and $t = 2$ s ?

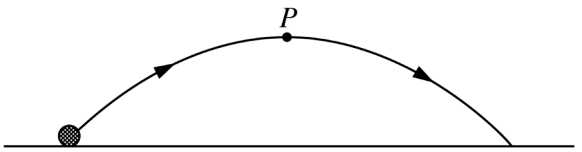
(A) $2b$

(B) $a + b$

(C) $a + 2b$

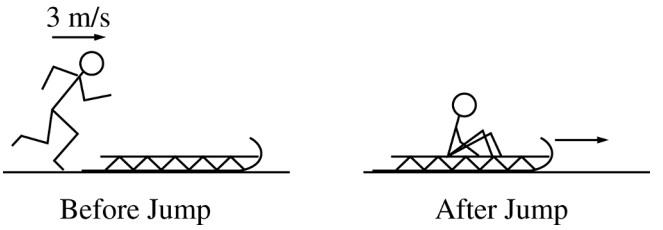
(D) $a + \frac{7}{3}b$

(E) $a + \frac{7}{2}b$



13. A ball is tossed and follows the trajectory shown above. Point P is the highest point on the trajectory, and air resistance is negligible. Which of the following statements is true of the ball while it is in motion?

(A) Its speed is constant.
(B) Its acceleration is constant.
(C) The horizontal component of its velocity is zero at point P.
(D) The vertical component of its velocity is a maximum at point P.
(E) Its kinetic energy is a maximum at point P.



14. As shown in the figure above, a child of mass 25 kg who is running at a speed of 3 m/s jumps onto a stationary sled of mass 5 kg on a frozen lake. The speed at which the child and sled begin to slide across the ice is most nearly

(A) 0.4 m/s
(B) 0.6 m/s
(C) 1.3 m/s
(D) 2.5 m/s
(E) 15 m/s

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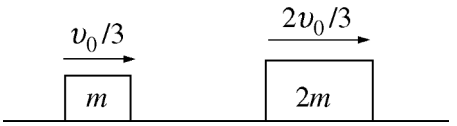
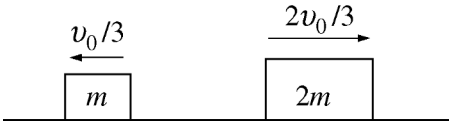
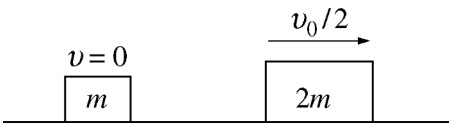
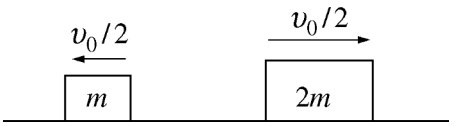
GO ON TO THE NEXT PAGE.

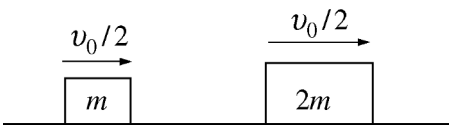
15. A block of mass m is initially sliding with speed v_0 on a horizontal frictionless surface, as shown above. It makes an elastic, head-on collision with another block of mass $2m$ that is initially at rest. Which of the following correctly shows the motion of the blocks after the collision?

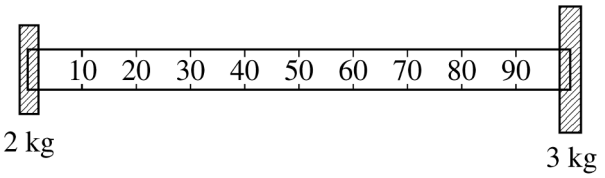
(A)


(B)


(C)


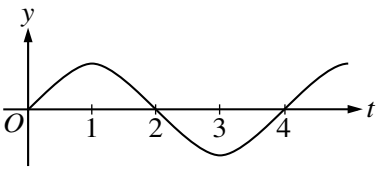
(D)


(E)




16. A 2 kg mass is attached to the 0 cm mark of a lightweight meter stick, and a 3 kg mass is attached to the 100 cm mark, as shown above. The center of mass of the combined system (meter stick and both masses) is located nearest which of the following marks on the meter stick?

(A) 33 cm
(B) 40 cm
(C) 60 cm
(D) 67 cm
(E) 75 cm



17. For a mass attached to a vertical spring, the vertical displacement y of the mass is given as a function of time t in the diagram above. At what time t does the mass experience a maximum positive acceleration?

(A) $t = 1$
(B) $t = 2$
(C) $t = 3$
(D) $t = 4$
(E) None of the above, since its acceleration is constant

18. For an object in simple harmonic motion with amplitude A, the kinetic energy will equal the potential energy when the displacement is

(A) zero
(B) $\pm A/4$
(C) $\pm A/2$
(D) $\pm A/\sqrt{2}$
(E) $\pm A$

19. Examples of simple harmonic motion include which of the following?

I. A mass, hanging from a spring, moves up and down in a uniform gravitational field.
II. A puck on an air table bounces back and forth between the walls of the table.
III. A ball bounces up and down on a table.

(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

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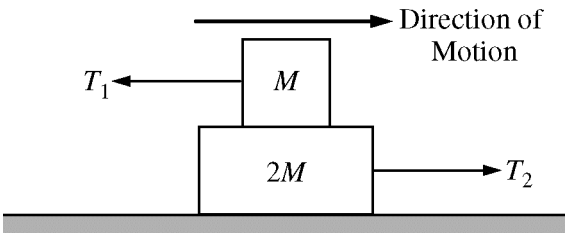
Questions 20-21



Two blocks are stacked on top of each other, as shown in the figure above. The top block, of mass M, is attached to a rope that pulls to the left with tension T_1. The bottom block, of mass $2M$, is attached to a rope that pulls to the right with tension T_2. The coefficient of friction between the blocks is μ. The blocks are at rest relative to each other and move to the right at constant speed relative to the frictionless surface.

20. What is the relationship between T_1 and T_2?

(A) $T_1 = 2T_2$

(B) $T_1 = \frac{1}{2}T_2$

(C) $T_1 = \mu T_2$

(D) $T_1 = \frac{1}{\mu}T_2$

(E) $T_1 = T_2$

21. The force of friction experienced by the top block is f_1, and the force of friction experienced by the bottom block is f_2. What is the relationship between f_1 and f_2?

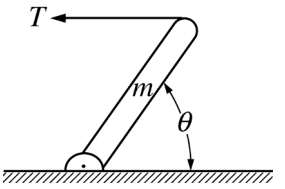
(A) $f_1 = 2f_2$

(B) $f_1 = \frac{1}{2}f_2$

(C) $f_1 = \mu f_2$

(D) $f_1 = \frac{1}{\mu}f_2$

(E) $f_1 = f_2$



22. A uniform beam of mass m is pivoted at one end and held in equilibrium at an angle θ by a horizontal wire, as shown above. The tension T in the wire is

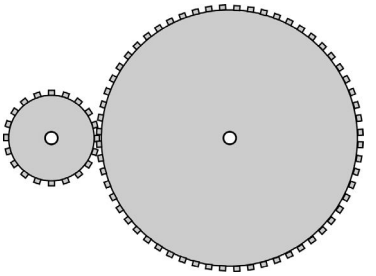
(A) $\frac{1}{2}mg\cot\theta$

(B) $mg\cot\theta$

(C) $mg\tan\theta$

(D) $2mg\tan\theta$

(E) mg



23. A gear containing 20 teeth on its circumference is meshed with a gear containing 60 teeth on its circumference, as shown above. If the angular speed of the 20-tooth gear is ω, what is the angular speed of the 60-tooth gear?

(A) $\frac{\omega}{60}$

(B) $\frac{\omega}{20}$

(C) $\frac{\omega}{3}$

(D) ω

(E) 3ω

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24. The angular displacement θ of a rotating wheel is described by the equation $\theta = \theta_0 + at^2 - bt^3$, where t is time and θ_0, a, and b are positive constants. The angular acceleration of the wheel as a function of time t is

(A) equal to a positive constant

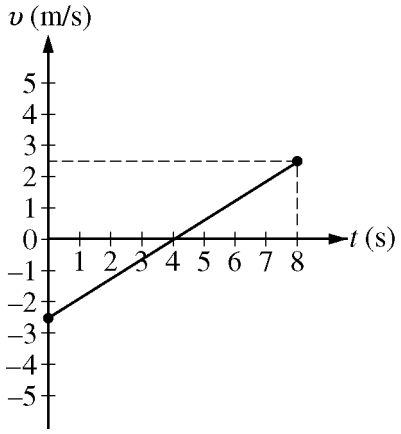
(B) zero

(C) $2a - 6bt$

(D) $2at - 3bt^2$

(E) $\theta_0 t + \frac{1}{3}at^3 - \frac{1}{4}bt^4$

Questions 25-27



The motion of an object moving along a straight line is described by the graph of velocity υ versus time t above.

25. Which of the following is true about the speed of the object during the time interval from 0 to 8 s?

(A) It increases during the entire interval.
(B) It decreases during the entire interval.
(C) It remains the same.
(D) It first increases and then decreases.
(E) It first decreases and then increases.

26. Which of the following is true about the acceleration of the object during the time interval from 0 to 8 s?

(A) It increases during the entire interval.
(B) It decreases during the entire interval.
(C) It remains the same.
(D) It first increases and then decreases.
(E) It first decreases and then increases.

27. What is the net displacement of the object for the time interval from 0 to 8 s?

(A) 0 m
(B) 5 m
(C) 10 m
(D) 20 m
(E) It cannot be determined without knowing the initial position of the object.

---

28. An object starts from rest and accelerates uniformly in the horizontal direction, moving 32 m during the first 4 s. What are the magnitudes of the object's displacement and velocity after it accelerates for the first 3 s

	Magnitude of Displacement	Magnitude of Velocity
(A)	24 m	24 m/s
(B)	24 m	18 m/s
(C)	18 m	18 m/s
(D)	18 m	12 m/s
(E)	8 m	12 m/s

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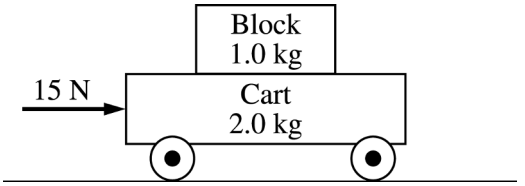

29. A 2.0 kg cart rolls with negligible friction on a horizontal surface, as shown in the figure above. The coefficient of static friction between the cart and the 1.0 kg block on top of the cart is 0.7. If a horizontal 15 N force is applied to the cart as shown and the block does not slide on the cart, the magnitude of the horizontal component of the force that the block exerts on the cart is most nearly

(A) 2 N
(B) 5 N
(C) 8 N
(D) 10 N
(E) 15 N

30. A car rounds a flat curve of radius R with a speed of v_0. The coefficient of friction between the tires and the road is μ. For the car not to slide on the road, which of the following statements must be true?

(A) The car's speed v_0 cannot be greater than μgR.
(B) The car's speed v_0 cannot be less than μgR.
(C) The radius R of the car's path cannot be greater than $v_0^2/\mu g$.
(D) The radius R of the car's path cannot be less than $v_0^2/\mu g$.
(E) The centripetal acceleration must be less than g.

31. If two balls collide and there are no external forces acting on the balls, quantities that must be the same for the two-ball system before and after the collision include which of the following?

I. Total kinetic energy
II. Total momentum
III. Momentum in the x-direction

(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

32. Two objects, X and Y, are released from rest at the same height. Object X has three times the mass of object Y. Just before reaching the ground, object Y has momentum p_Y and kinetic energy K_Y. If air resistance is negligible, what are the momentum and kinetic energy of object X just before it reaches the ground?

	Momentum	Kinetic Energy
(A)	p_Y	K_Y
(B)	$3p_Y$	$3K_Y$
(C)	$3p_Y$	$6K_Y$
(D)	$6p_Y$	$3K_Y$
(E)	$6p_Y$	$6K_Y$

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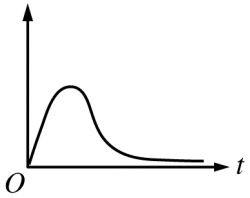
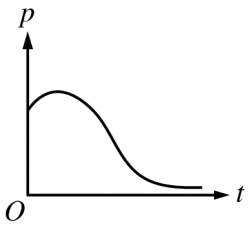
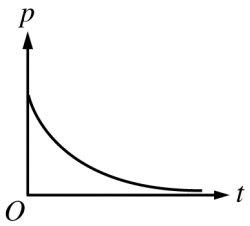
Questions 33-34

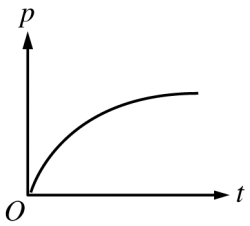
A very light ball is released from rest at time $t = 0$ and falls through the air, which provides significant resistance.

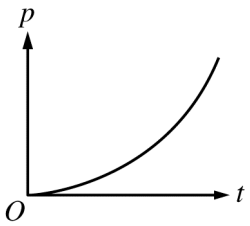
33. Which graph best represents the magnitude of the momentum of the ball?

(A)


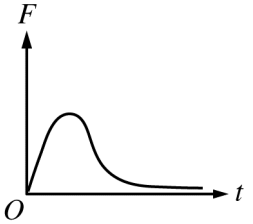
(B)


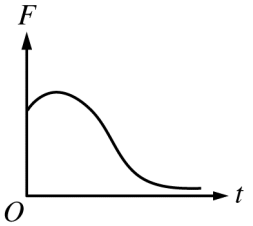
(C)


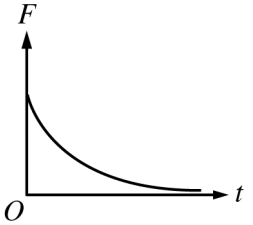
(D)


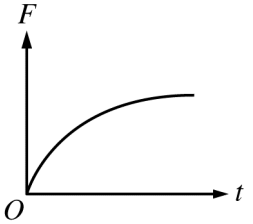
(E)


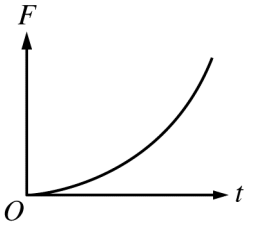
34. Which graph best represents the magnitude of the net force on the ball?

(A)


(B)


(C)


(D)


(E)


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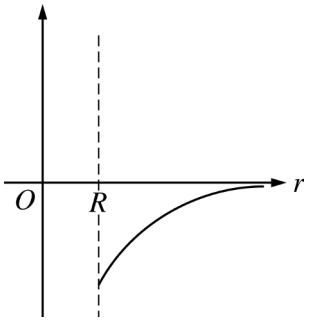
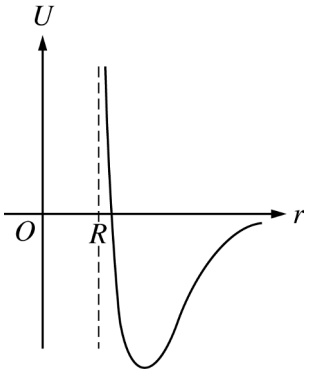
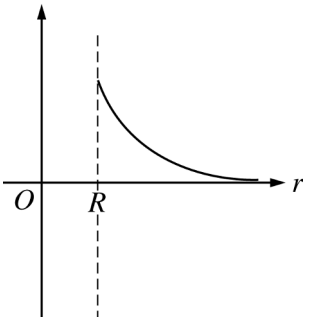
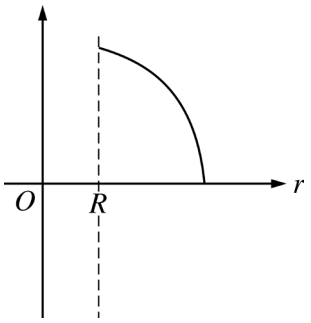
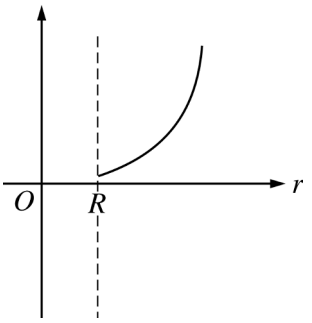
35. A satellite can move in a circular orbit about a massive planet of radius R. Which of the following graphs could represent the gravitational potential energy U of this satellite as a function of the radius r of the orbit?

(A)


(B)


(C)


(D)


(E)


S T O P

END OF MECHANICS SECTION I

IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON MECHANICS SECTION I ONLY.

DO NOT TURN TO ANY OTHER TEST MATERIALS.

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**

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Section II: Free-Response Questions

This is the free-response section of the 2014 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 C: Mechanics Exam

SECTION II: Free Response

2014

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

At a Glance

Total Time
45 minutes
Number of Questions
3
Percent of Total Score
50%
Writing Instrument
Either pencil or pen with black or dark blue ink
Electronic Device
Calculator allowed
Weight
The questions are weighted equally.

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 4JBP6-S

TABLE OF INFORMATION, EFFECTIVE 2012

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	1 electron volt, $1 \text{ eV} = 1.60 \times 10^{-19}$ J
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Speed of light, $c = 3.00 \times 10^{8}$ m/s
Avogadro's number, $N_0 = 6.02 \times 10^{23}$ mol^{-1}	Universal gravitational constant, $G = 6.67 \times 10^{-11}$ m^3/kg·s^2
Universal gas constant, $R = 8.31$ J/(mol·K)	Acceleration due to gravity at Earth's surface, $g = 9.8$ m/s^2
Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K	

1 unified atomic mass unit,	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg} = 931 \text{ MeV}/c^2$
Planck's constant,	$h = 6.63 \times 10^{-34}$ J·s $= 4.14 \times 10^{-15}$ eV·s
	$hc = 1.99 \times 10^{-25}$ J·m $= 1.24 \times 10^{3}$ eV·nm
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}$ C^2/N·m^2
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9}$ N·m^2/C^2
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ (T·m)/A
Magnetic constant,	$k' = \mu_0/4\pi = 1 \times 10^{-7}$ (T·m)/A
1 atmosphere pressure,	$1 \text{ atm} = 1.0 \times 10^{5}$ N/m^2 $= 1.0 \times 10^{5}$ Pa

UNIT SYMBOLS								
	meter,	m	mole,	mol	watt,	W	farad,	F
	kilogram,	kg	hertz,	Hz	coulomb,	C	tesla,	T
	second,	s	newton,	N	volt,	V	degree Celsius,	°C
	ampere,	A	pascal,	Pa	ohm,	Ω	electron-volt,	eV
	kelvin,	K	joule,	J	henry,	H		

PREFIXES		
Factor	Prefix	Symbol
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. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.
II. The direction of any electric current is the direction of flow of positive charge (conventional current).
III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

ADVANCED PLACEMENT PHYSICS C EQUATIONS, EFFECTIVE 2012

MECHANICS

$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$v^2 = v_0^2 + 2a(x - x_0)$

$\sum \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$

$\mathbf{F} = \frac{d\mathbf{p}}{dt}$

$\mathbf{J} = \int \mathbf{F}\,dt = \Delta\mathbf{p}$

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

$F_{fric} \le \mu N$

$W = \int \mathbf{F} \cdot d\mathbf{r}$

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

$P = \frac{dW}{dt}$

$P = \mathbf{F} \cdot \mathbf{v}$

$\Delta U_g = mgh$

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

$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$

$\sum \boldsymbol{\tau} = \boldsymbol{\tau}_{net} = I\boldsymbol{\alpha}$

$I = \int r^2 dm = \sum mr^2$

$\mathbf{r}_{cm} = \sum m\mathbf{r} / \sum m$

$v = r\omega$

$\mathbf{L} = \mathbf{r} \times \mathbf{p} = I\boldsymbol{\omega}$

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

$\omega = \omega_0 + \alpha t$

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

a = acceleration
F = force
f = frequency
h = height
I = rotational inertia
J = impulse
K = kinetic energy
k = spring constant
ℓ = length
L = angular momentum
m = mass
N = normal force
P = power
p = momentum
r = radius or distance
$\mathbf{r}$ = position vector
T = period
t = time
U = potential energy
v = velocity or speed
W = work done on a system
x = position
μ = coefficient of friction
θ = angle
τ = torque
ω = angular speed
α = angular acceleration
ϕ = phase angle

$\mathbf{F}_s = -k\mathbf{x}$

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

$x = x_{\max}\cos(\omega t + \phi)$

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

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

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

$\mathbf{F}_G = -\frac{Gm_1m_2}{r^2}\hat{\mathbf{r}}$

$U_G = -\frac{Gm_1m_2}{r}$

ELECTRICITY AND MAGNETISM

$F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$

$\mathbf{E} = \frac{\mathbf{F}}{q}$

$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\epsilon_0}$

$E = -\frac{dV}{dr}$

$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$

$U_E = qV = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}$

$C = \frac{Q}{V}$

$C = \frac{\kappa\epsilon_0 A}{d}$

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$I = \frac{dQ}{dt}$

$U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$

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

$\mathbf{E} = \rho\mathbf{J}$

$I = Nev_dA$

$V = IR$

$R_s = \sum_i R_i$

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

$P = IV$

$\mathbf{F}_M = q\mathbf{v} \times \mathbf{B}$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = emf
F = force
I = current
J = current density
L = inductance
ℓ = length
n = number of loops of wire per unit length
N = number of charge carriers per unit volume
P = power
Q = charge
q = point charge
R = resistance
r = distance
t = time
U = potential or stored energy
V = electric potential
v = velocity or speed
ρ = resistivity
ϕ_m = magnetic flux
κ = dielectric constant

$\oint \mathbf{B} \cdot d\boldsymbol{\ell} = \mu_0 I$

$d\mathbf{B} = \frac{\mu_0}{4\pi}\frac{I\,d\boldsymbol{\ell} \times \mathbf{r}}{r^3}$

$\mathbf{F} = \int I\,d\boldsymbol{\ell} \times \mathbf{B}$

$B_s = \mu_0 nI$

$\phi_m = \int \mathbf{B} \cdot d\mathbf{A}$

$\mathcal{E} = \oint \mathbf{E} \cdot d\boldsymbol{\ell} = -\frac{d\phi_m}{dt}$

$\mathcal{E} = -L\frac{dI}{dt}$

$U_L = \frac{1}{2}LI^2$

ADVANCED PLACEMENT PHYSICS C EQUATIONS, EFFECTIVE 2012

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

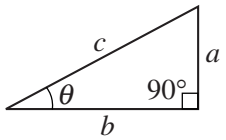
Right Triangle

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

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

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

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



CALCULUS

$$\frac{df}{dx} = \frac{df}{du}\frac{du}{dx}$$

$$\frac{d}{dx}\left(x^n\right) = nx^{n-1}$$

$$\frac{d}{dx}\left(e^x\right) = e^x$$

$$\frac{d}{dx}(\ln x) = \frac{1}{x}$$

$$\frac{d}{dx}(\sin x) = \cos x$$

$$\frac{d}{dx}(\cos x) = -\sin x$$

$$\int x^n\,dx = \frac{1}{n+1}x^{n+1},\ n \neq -1$$

$$\int e^x\,dx = e^x$$

$$\int \frac{dx}{x} = \ln|x|$$

$$\int \cos x\,dx = \sin x$$

$$\int \sin x\,dx = -\cos x$$

PHYSICS C: MECHANICS
SECTION II
Time—45 minutes
3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.

Mech 1.

Experiment 1: A block of mass 1.5 kg is placed on a long board. You are to design an experiment to determine the coefficient of static friction between the block and the board.

(a)

i. From the following list of available equipment, check those additional items you would use for the purpose of determining the coefficient of static friction.

____ Ruler ____ Spring scale ____ String

____ Meterstick ____ Pulley ____ Protractor

____ Photogate ____ Stopwatch ____ Mass hanger

____ Clamps and supports ____ Objects of various known masses

ii. Sketch a diagram of your experimental setup and label the pieces of equipment that would be used.

iii. Outline the experimental procedure you would use, including a list of quantities you would measure. For each quantity, identify the equipment you would use to make the measurement.

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(b) Explain how to use the measurements described in part (a) to calculate the coefficient of static friction. Include a free-body diagram in your explanation that shows all forces (not components) acting on the block while the measurements are being made.

Experiment 2: In a second experiment, the coefficient of kinetic friction between the block and the board is determined to be 0.10. The board is now inclined at an angle of 25° above the horizontal. The block is released from rest at the top of the incline and slides 2.0 m down the incline.

(c) Calculate the work done by kinetic friction as the block slides down the incline.

(d) The mass of the block is now increased without changing the coefficient of kinetic friction, and experiment 2 is repeated. How does each of the following change?

i. The magnitude of the frictional force

__ Increases __ Decreases __ Remains the same

ii. The magnitude of the velocity of the block as it reaches the bottom of the incline

__ Increases __ Decreases __ Remains the same

iii. The kinetic energy of the block at the bottom of the incline

__ Increases __ Decreases __ Remains the same

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Mech 2.

A satellite of mass m is in a stable circular orbit around Earth at a distance R_1 from the center of Earth. The mass of Earth is M_e.

(a) Derive an expression for the following in terms of m, R_1, M_e, and fundamental constants, as appropriate.

i. The orbital speed υ_1 of the satellite

ii. The total energy of the satellite in this orbit, assuming gravitational potential energy to be zero at an infinite distance from the center of Earth

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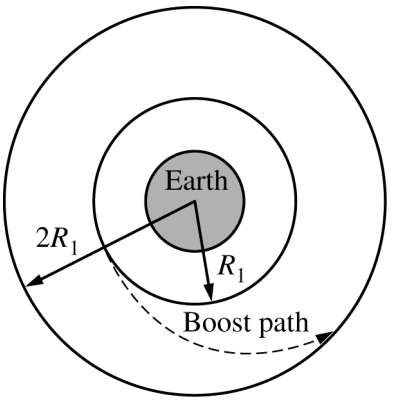
The satellite's booster rockets fire and lift the satellite to a higher circular orbit of radius $2R_1$. The satellite follows the path shown in the diagram below, moving a total distance S during the orbital change. The component of the rockets' force parallel to the path is given by the equation $F = F_0\left(1 - \frac{x}{S}\right)$, where x is the variable distance traveled along the path at any moment.



(b) Derive an expression for the total work done on the satellite by the force F in terms of F_0 and S.

(c) If the total distance S is equal to $3R_1$, derive an expression for F_0 in terms of M_e, R_1, m, and fundamental constants, as appropriate.

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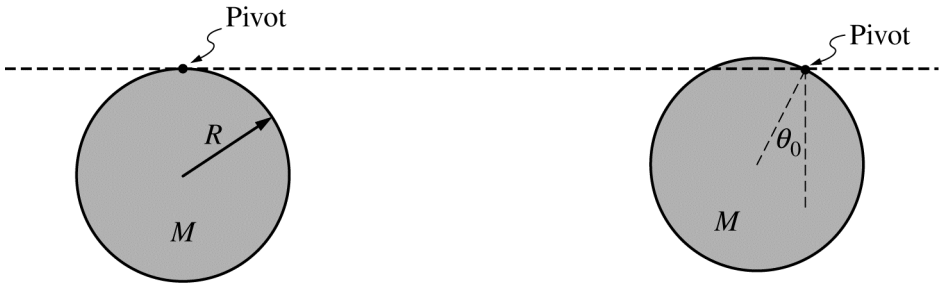

Figure 1 Figure 2

Mech 3.

A uniform disk of mass M and radius R is suspended vertically from a pivot on its edge so that it is free to swing without friction, as shown in Figure 1 above. The disk is raised to an initial angular displacement θ_0 with respect to the vertical, as shown in Figure 2 above, and released from rest. The rotational inertia of the disk about its center of mass is $I = MR^2/2$. Express all algebraic answers in terms of the given quantities and fundamental constants, as appropriate.

(a) Derive an expression for the rotational inertia of the disk about the pivot.

(b) Derive an expression for the maximum angular velocity of the disk during its swing.

(c) Using Newton's second law in either translational or rotational form, as appropriate, write a differential equation that could be used to determine the angular displacement of the disk θ as a function of time t. Do not solve the equation.

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GO ON TO THE NEXT PAGE.

(d) Derive an expression for the period for small-amplitude oscillations of the disk.

(e) Suppose the disk is replaced with another uniform disk with twice the radius, and the pivot point is again on the edge of the disk. How will the period of small-amplitude oscillations be affected by the new disk?

__ It will increase. __ It will decrease. __ It will remain the same.

__ There is not enough information to determine the period.

Justify your answer.

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THIS PAGE MAY BE USED FOR SCRATCH WORK.

STOP

END OF EXAM

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 <u>AND</u> BACK COVERS OF THE SECTION II BOOKLET.**
- **CHECK TO SEE THAT YOUR AP NUMBER LABEL APPEARS IN THE BOX(ES) ON THE COVER(S).**
- **MAKE SURE YOU HAVE USED THE SAME SET OF AP NUMBER LABELS ON <u>ALL</u> 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 C: Mechanics Practice Exam, Section I

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

Free-Response Scoring Guidelines

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

Question 1

15 points total | **Distribution of points**

(a)

i. 1 point

For selecting equipment consistent with the diagram drawn in part (a)-ii — 1 point

ii. 1 point

For labeling a diagram consistent with the procedure in described part (a)-iii — 1 point

iii. 2 points

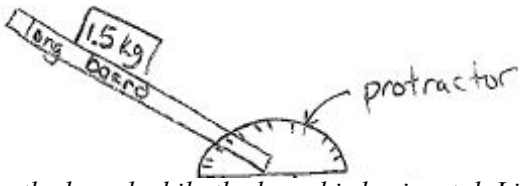
For listing specific quantities to be measured that can be used to determine the coefficient of static friction — 1 point

For indicating which equipment will be used to take the measurements listed above — 1 point

Example:

Pull the spring scale to the right until the block starts to move. Use the spring scale to measure the maximum force exerted on the block.

Alternate Example:



Place the block on the board while the board is horizontal. Lift one end of the board until the block begins to slide. Use a protractor to measure the angle at which the block begins to slide.

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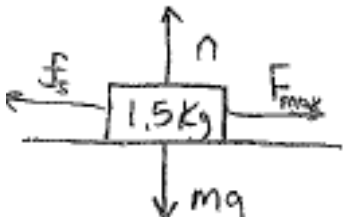
Question 1 (continued)

Distribution of points

(b) 5 points

The experiment described by the student must attempt to measure the coefficient of static friction μ_s, not the coefficient of kinetic friction.

Solution for example shown above:



For vectors indicating the normal force up and the force of gravity down — 1 point
For a vector indicating the horizontal applied force — 1 point
For a vector indicating the static friction opposite the applied force — 1 point
Note: One point is deducted if there are any extraneous vectors or any vectors not starting on and pointing away from the block.
For setting the net force equal to zero — 1 point

$F_{net} = ma = 0$

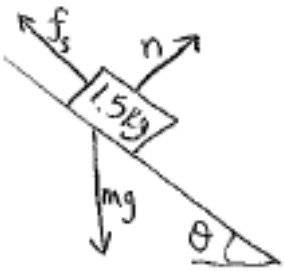
$F_{\max} - f_s = 0$

$f_s = \mu_s mg$

For a correct expression for the coefficient of static friction — 1 point

$\mu_s = \dfrac{F_{\max}}{mg}$

Solution for alternate example: — *Alternate points*



For a vector indicating the force of gravity down — *1 point*
For a vector indicating the normal force perpendicular to the incline — *1 point*
For a vector indicating the static friction up the incline — *1 point*
Note: One point is deducted if there are any extraneous vectors or any vectors not starting on and pointing away from the block
For setting the net force equal to zero — *1 point*

$F_{net} = ma = 0$

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Question 1 (continued)

	Distribution of points
$F_{\max} - f_s = 0$	
$F_{\max}$ is the component of gravity along the plane, and f_s depends on the component of gravity perpendicular to the plane	
$mg\sin\theta - \mu_s mg\cos\theta = 0$	
For a correct expression for the coefficient of static friction	1 point
$\mu_s = \tan\theta$	

(c) 3 points

For a correct equation to solve for the work done	1 point
$W = F \bullet d = -f_k d$	
$W = -\mu_k mg\cos\theta d$	
For correctly substituting for the force of kinetic friction	1 point
$W = -(0.10)(1.5\text{ kg})(9.8\text{ m/s}^2)(\cos 25)(2.0\text{ m})$	
For a correct answer	1 point
$W = -2.7\text{ J}$	
Note: Answers without the negative sign only lose the answer point.	

(d)

i. 1 point

For selecting "Increases"	1 point

ii. 1 point

For selecting "Remains the same"	1 point

iii. 1 point

For selecting "Increases"	1 point

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Question 2

15 points total | **Distribution of points**

(a)

i. 3 points

Set the gravitational force equal to the centripetal force.

$F_g = F_C$

For a correct expression for the gravitational force — 1 point

For a correct expression for the centripetal force — 1 point

$$\frac{GM_e m}{R_1^2} = \frac{m\upsilon_1^2}{R_1}$$

For a correct answer — 1 point

$$\upsilon_1 = \sqrt{\frac{GM_e}{R_1}}$$

ii. 3 points

For an expression of the total energy as the sum of the gravitational potential energy and the kinetic energy of the satellite — 1 point

$E = U_g + K$

For substituting a correct expression for the kinetic energy of the satellite — 1 point

$$E = -\frac{GM_e m}{R_1} + \frac{1}{2}m\upsilon_1^2$$

$$E = -\frac{GM_e m}{R_1} + \frac{1}{2}m\left(\frac{GM_e}{R_1}\right)$$

For a correct answer — 1 point

$$E = -\frac{GM_e m}{2R_1}$$

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Question 2 (continued)

Distribution of points

(b) 4 points

For a correct equation for the work done expressed as the integral of the force — 1 point

$$W = \int F \bullet ds$$

For substituting the given expression for force into the above equation — 1 point

$$W = \int_0^S F_0 \left(1 - \frac{x}{S}\right) dx$$

For integrating with the correct limits — 1 point

$$W = F_0 \left[x - \frac{x^2}{2S} \right]_0^S$$

$$W = F_0 \left(S - \frac{S^2}{2S} - 0 \right) = F_0 \left(\frac{S}{2} \right)$$

For a correct answer — 1 point

$$W = \frac{F_0 S}{2}$$

(c) 5 points

For a correct statement relating work and change in energy — 1 point

$$W = \Delta E$$

For substituting the correct initial radius into the expression for potential energy — 1 point

For substituting the correct final radius into the expression for potential energy — 1 point

$$W = \Delta E = -\frac{GM_e m}{4R_1} - \left(-\frac{GM_e m}{2R_1} \right)$$

For a correct substitution of the answer from part (b) — 1 point

$$\frac{F_0 S}{2} = -\frac{GM_e m}{4R_1} + \frac{GM_e m}{2R_1}$$

$$\frac{F_0 (3R_1)}{2} = \frac{GM_e m}{4R_1}$$

For an answer consistent with part (b) and the change in energy — 1 point

$$F_0 = \frac{GM_e m}{6R_1^2}$$

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Question 3

15 points total | **Distribution of points**

(a) 2 points

For a correct expression of the parallel axis theorem — 1 point

$I = I_{CM} + Md^2$

Substitute into the above expression

$I = \frac{1}{2}MR^2 + MR^2$

For a correct answer — 1 point

$I = \frac{3}{2}MR^2$

(b) 4 points

For a correct expression of the conservation of energy for the disk — 1 point

$K_1 + U_1 = K_2 + U_2$

For correctly setting the initial gravitational potential energy equal to the rotational kinetic energy at the bottom of the swing — 1 point

$mgh_1 = \frac{1}{2}I\omega^2$

For substituting a correct expression for the initial height — 1 point

$Mg\left(R - R\cos\theta_0\right) = \frac{1}{2}\left(\frac{3}{2}MR^2\right)\omega^2$

$g\left(1 - \cos\theta_0\right) = \frac{3}{4}R\omega^2$

For an answer consistent with part (a) — 1 point

$\omega = \sqrt{\frac{4g}{3R}\left(1 - \cos\theta_0\right)}$

(c) 3 points

For using a correct expression of Newton's 2nd law for rotational motion — 1 point

$\tau = I\alpha = \frac{3}{2}MR^2\alpha$

For substituting a correct expression for torque into the above equation — 1 point

$-Mg\sin\theta R = \frac{3}{2}MR^2\alpha$

For expressing the above equation as a differential equation (Note: Any appropriate manipulation of this equation is acceptable, including a subsequent small angle approximation.) — 1 point

$-g\sin\theta = \frac{3}{2}R\frac{d^2\theta}{dt^2}$

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Question 3 (continued)

Distribution of points

(d) 4 points

For using a correct expression for simple harmonic motion — 1 point

$a = -\omega^2 x$

$\frac{d^2\theta}{dt^2} = -\omega^2\theta$

For substituting the small angle approximation ($\sin\theta \approx \theta$) into the answer from part (c) — 1 point

$-g\theta = \frac{3}{2}R\frac{d^2\theta}{dt^2}$

$-\frac{2g}{3R}\theta = \frac{d^2\theta}{dt^2}$

$\omega = \sqrt{\frac{2g}{3R}}$

For relating the correct expression for the angular velocity to the equation for period — 1 point

$\omega = \sqrt{\frac{2g}{3R}} = \frac{2\pi}{T}$

For a correct answer — 1 point

$T = 2\pi\sqrt{\frac{3R}{2g}}$

(e) 2 points

For selecting "It will increase" — 1 point

For a correct justification — 1 point

Example:

The period of the disk is proportional to the square root of the radius of the disk, $T \propto \sqrt{R}$. A doubling of the radius of the disk will increase the period by a factor of $\sqrt{2}$.

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Scoring Worksheet

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

2014 AP Physics C: Mechanics Scoring Worksheet

Section I: Multiple Choice

_____	× 1.2857 =	_____
Number Correct (out of 35)		Weighted Section I Score (Do not round)

Section II: Free Response

Question 1	_____ (out of 15)	× 1.0000 =	_____ (Do not round)
Question 2	_____ (out of 15)	× 1.0000 =	_____ (Do not round)
Question 3	_____ (out of 15)	× 1.0000 =	_____ (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 C: Mechanics

Composite Score Range	AP Score
55-90	5
44-54	4
37-43	3
29-36	2
0-28	1

AP Physics C: Mechanics

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