CollegeBoard

AP® Physics C: Mechanics Practice Exam

From the 2012 Administration

Contents

<u>Note:</u> This publication shows the page numbers that appeared in the *2011−12 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 ***2011–12 AP Exam Instructions*** book.

AP® Physics C: Mechanics Exam

Regularly Scheduled Exam Date: Monday afternoon, May 14, 2012

Late-Testing Exam Date: Friday afternoon, May 25, 2012

Section I: At a Glance

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

Section II: 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.

Section I: Multiple Choice Booklet 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.

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.

Section II: Free Response Booklet 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.

What Proctors Need to Bring to This Exam

- Exam packets
- Answer sheets
- AP Student Packs
- *2011-12 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, programmable, or graphing calculators on parts of this exam. Review the section "Calculator Policy" on pages 40–42 of the *2011-12 AP Coordinator's Manual*. 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 42 of the *2011-12 AP Coordinator's Manual*. If a student does not have a 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 41 of the *2011-12 AP Coordinator's Manual*. Rulers and straightedges may be used for the entire exam. 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.

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 14, 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 25, 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 *2011-12 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. . . .

Look at page 1 of your answer sheet and locate the dark blue box near the top right-hand corner that states, "Take the AP Exam label from your Section I booklet and place the label here.". . .

Now look at the front cover of your exam booklet and locate the AP Exam label near the top left of the cover. . . .

Carefully peel off the AP Exam label and place it on your answer sheet on the dark blue box that we just identified. . . .

Now 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 on 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 read 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 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 calculators' infrared ports are not facing each other. 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 these specific free-response questions with anyone unless they are released on the College Board website in about two days. You should receive your score report in the mail about the third week of 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. You should receive your score report in the mail about the third week of 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.

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. Failure to adhere to any of these rules could result in cancellation of your score. 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 213 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 view 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 *2011-12 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 2012 Answer Sheet

Take an AP Number label from your AP Student Pack and place the label here.

B123456789T

Take the AP Exam label from your Section I booklet and place the label here.

CollegeBoard

NAME AND EXAM AREA — COMPLETE THIS AREA AT EVERY EXAM.

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 the completion of the section. I am aware of and agree to the AP Program's policies and procedures as outlined in the *2011-12 Bulletin for AP Students and Parents*, including using testing accommodations (e.g., extended time, computer, etc.) only if I have been preapproved by College Board Services for Students with Disabilities.

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

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

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

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

USE NO. 2 PENCIL ONLY

C. YOUR AP NUMBER — 0 1 2 3 4 5 6 7 8 9

D. EXAM DATE — Month: 0 1; Day: 0 1 2 3 4 5 6 7 8 9

E. EXAM START TIME — AM: 6 7 8 9 10 11; PM: 12 1 2 3 4 5

F. MULTIPLE-CHOICE BOOKLET SERIAL NUMBER — S — 0 1 2 3 4 5 6 7 8 9

G. ONLINE PROVIDER CODE — 0 1 2 3 4 5 6 7 8 9

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

STUDENT INFORMATION AREA — COMPLETE THIS AREA ONLY ONCE.

I. DATE OF BIRTH — Month: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec; Day; Year

J. SEX — Female, Male

K. CURRENT GRADE LEVEL — Pre-9th, 9th, 10th, 11th, 12th, Post-12th

L. SOCIAL SECURITY NUMBER (Optional)

M. EXPECTED DATE OF COLLEGE ENTRANCE — Fall, Winter/Spring, Summer, Undecided; 2012, 2013, 2014, 2015

N. STUDENT SEARCH SERVICE®

I want the College Board to send information about me to colleges, universities and government scholarship programs interested in students like me.

Yes — No

O. WHICH LANGUAGE DO YOU KNOW BEST?

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

P. 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

Q. 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

SCHOOL USE ONLY

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

Fee Reduction Granted: 1 Option 1 — 2 Option 2

ETS USE ONLY

Exam — 0 1 2 3 4 5 6 7 8 9

Exam — 0 1 2 3 4 5 6 7 8 9

762000

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

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

S. 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, or Spanish Literature 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

Indicate your answers to the exam questions in this section. If a question has only four answer options, do not mark option E. Your answer sheet will be scored by machine. Use only No. 2 pencils to mark your answers on pages 2 and 3 (one response per question). After you have determined your response, be sure to completely fill in the corresponding circle next to the number of the question you are answering. Stray marks and smudges could be read as answers, so erase carefully and completely. Any improper gridding may affect your score. Answers written in the multiple-choice booklet will not be scored.

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

ETS USE ONLY	48, 55, 62, 75, 87		R	W	O	OTHER		R	W	O
		PT02					TOTAL			
		PT03								
		PT04								

DO NOT WRITE IN THIS AREA

QUESTIONS 76–120

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

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

DO NOT WRITE IN THIS AREA

HOME ADDRESS AND SCHOOL AREA — COMPLETE THIS AREA ONLY ONCE.

T. 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.)

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z 0 1 2 3 4 5 6 7 8 9 /

CITY

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

ZIP OR POSTAL CODE

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z 0 1 2 3 4 5 6 7 8 9 /

COUNTRY CODE

0 1 2 3 4 5 6 7 8 9

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, Other

U. AREA CODE AND PHONE NUMBER

0 1 2 3 4 5 6 7 8 9

INTERNATIONAL PHONE

V. SCHOOL YOU ATTEND

SCHOOL CODE

0 1 2 3 4 5 6 7 8 9

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W. COLLEGE TO RECEIVE YOUR AP SCORE REPORT

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Section I: Multiple-Choice Questions

This is the multiple-choice section of the 2012 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.)

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AP® Physics C: Mechanics Exam

SECTION I: Multiple Choice

2012

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.

PLACE SEAL HERE

PLACE SEAL HERE
DO NOT seal answer sheet inside

Form I
Form Code 4IBP4-S
80

TABLE OF INFORMATION DEVELOPED FOR 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, $G = 6.67 \times 10^{-11}$ $\text{m}^3/\text{kg}\cdot\text{s}^2$
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,	$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s} = 4.14 \times 10^{-15} \text{ eV}\cdot\text{s}$
	$hc = 1.99 \times 10^{-25} \text{ J}\cdot\text{m} = 1.24 \times 10^{3} \text{ eV}\cdot\text{nm}$
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9} \text{ N}\cdot\text{m}^2/\text{C}^2$
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,	$1 \text{ atm} = 1.0 \times 10^{5} \text{ N/m}^2 = 1.0 \times 10^{5}$ 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.

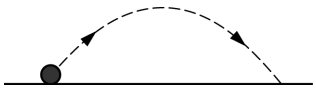
IV. For mechanics and thermodynamics equations, *W* represents the work done <u>on</u> a system.

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

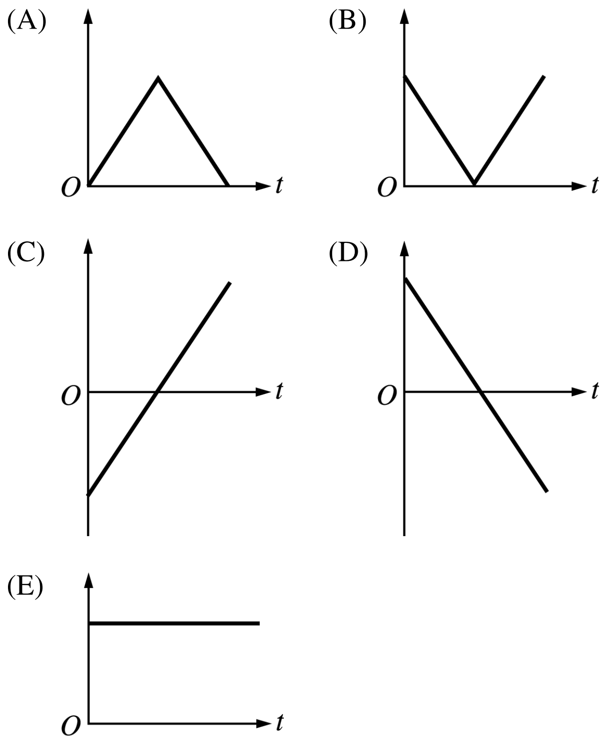
Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

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

Questions 1-2

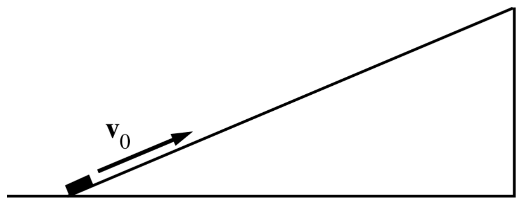


A ball is struck at time $t = 0$ and follows the parabolic path shown in the diagram above. The following graphs show quantities possibly associated with the motion as a function of time t. Assume that air resistance is negligible and that the positive directions are upward and to the right.



1. Which graph represents the horizontal component of the velocity of the ball?

2. Which graph represents the vertical component of the velocity of the ball?



3. An object with initial velocity $\mathbf{v}_0$, as shown above, slides up and then down a long, frictionless, inclined plane. Which of the following is true of the object as it moves?

   (A) It has a constant acceleration while moving up the plane and a greater acceleration when moving down the plane.
   (B) It has a constant acceleration while moving up the plane and a smaller acceleration when moving down the plane.
   (C) It moves with a constant velocity both up and down the plane.
   (D) It has the same acceleration as it moves up and down the plane.
   (E) It has a continually varying acceleration as it moves up and down the plane.

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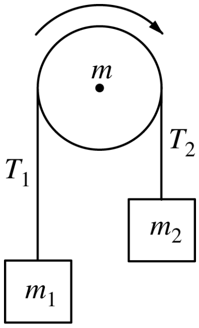
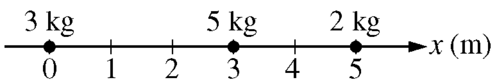


4. Two blocks of masses m_1 and m_2 are connected by a massless string that passes over a wheel of mass m, as shown above. The string does not slip on the wheel and exerts forces T_1 and T_2 on the blocks. When the wheel is released from rest in the position shown, it undergoes an angular acceleration and rotates clockwise. Which of the following statements about T_1 and T_2 is correct?

(A) $T_1 = T_2$ because the wheel has mass.
(B) $T_1 = T_2$ because both blocks have the same acceleration.
(C) $T_1 > T_2$ because m_1 is farther from the wheel than m_2.
(D) $T_1 > T_2$ because m_1 accelerates upward.
(E) $T_2 > T_1$ because an unbalanced clockwise torque is needed to accelerate the wheel clockwise.



5. Three objects are located along the x-axis as shown above. The center of mass of the objects is at $x =$

(A) 1.0 m
(B) 1.5 m
(C) 2.0 m
(D) 2.5 m
(E) 3.0 m

6. Which of the following is equivalent to a unit of momentum?

(A) Joule
(B) Newton
(C) Joule · second
(D) Newton · second
(E) Newton · meter

7. Two objects are dropped from rest from the same height. Object A falls through a distance d_A during a time t, and object B falls through a distance d_B during a time $2t$. If air resistance is negligible, what is the relationship between d_A and d_B?

(A) $d_A = \frac{1}{4} d_B$
(B) $d_A = \frac{1}{2} d_B$
(C) $d_A = 2d_B$
(D) $d_A = 4d_B$
(E) It cannot be determined from the information given.

GO ON TO THE NEXT PAGE.

8. The maximum mass that can be hung vertically from a string without breaking the string is 10 kg. A length of this string that is 2 m long is used to rotate a 0.5 kg object in a circle on a frictionless table with the string horizontal. The maximum speed that the mass can attain under these conditions without the string breaking is most nearly

(A) 5 m/s
(B) 10 m/s
(C) 14 m/s
(D) 20 m/s
(E) 100 m/s

9. An object moving on a horizontal, frictionless surface makes a glancing collision with another object initially at rest on the surface. In this case which of the following is true about momentum and kinetic energy?

(A) Momentum is always conserved, and kinetic energy may be conserved.
(B) Kinetic energy is always conserved, and momentum may be conserved.
(C) Momentum is always conserved, and kinetic energy is never conserved.
(D) Both momentum and kinetic energy are always conserved.
(E) Neither momentum nor kinetic energy is conserved.

10. A particle of mass m starts from rest at position $x = 0$ and time $t = 0$. It moves along the positive x-axis under the influence of a single force $F_x = bt$, where b is a constant. The velocity v of the particle is given by

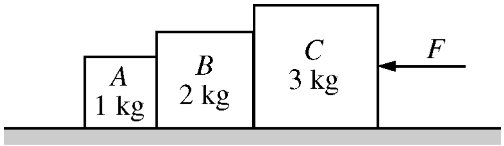
(A) $\frac{bt}{m}$

(B) $\frac{bt^2}{2m}$

(C) $\frac{bt^2}{m}$

(D) $\frac{b\sqrt{t}}{m}$

(E) $\frac{b}{mt}$

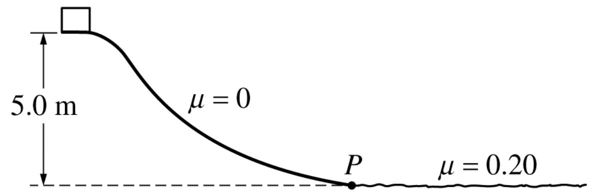


11. Three blocks, A, B, and C, of masses 1, 2, and 3 kg, respectively, are initially at rest on a frictionless surface as indicated in the figure above. What force F has to be applied on block C to accelerate the three blocks at 2 $\mathrm{m/s^2}$?

(A) 0.33 N
(B) 1.5 N
(C) 3.0 N
(D) 6.0 N
(E) 12 N

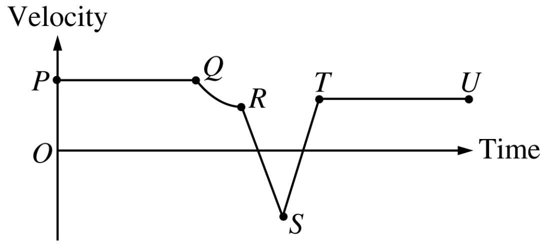
12. An electrical motor provides 0.50 W of mechanical power. How much time will it take the motor to lift a 0.1 kg mass at constant speed from the floor to a shelf 2.0 m above the floor?

(A) 0.25 s
(B) 0.40 s
(C) 1.0 s
(D) 2.0 s
(E) 4.0 s



13. A block slides from rest with negligible friction down the track above, descending a vertical height of 5.0 m to point P at the bottom. It then slides on the horizontal surface. The coefficient of friction between the block and the horizontal surface is 0.20. How far does the block slide on the horizontal surface before it comes to rest?

(A) 0.40 m
(B) 1.0 m
(C) 2.5 m
(D) 10 m
(E) 25 m



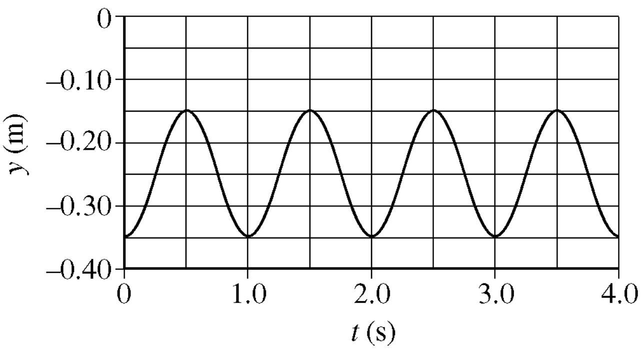
14. The graph above shows velocity as a function of time for an object moving along a straight line. For which of the following sections of the graph is the acceleration constant and nonzero?

(A) QR only
(B) ST only
(C) PQ and TU only
(D) RS and ST only
(E) PQ, RS, ST, and TU

15. The velocity of a particle moving along the x-axis is given as a function of time by the expression $v(t) = 3.0t^2 - 2.0t + 4.0$, where v is in meters per second and t is in seconds. What is the acceleration of the particle at $t = 2.0$ s?

(A) 4.0 m/s^2
(B) 6.0 m/s^2
(C) 8.0 m/s^2
(D) 10.0 m/s^2
(E) 12.0 m/s^2

Questions 16-17



An unstretched ideal spring hangs vertically from a fixed support. A 0.4 kg object is then attached to the lower end of the spring. The object is pulled down to a distance of 0.35 m below the unstretched position and released from rest at time $t = 0$. A graph of the subsequent vertical position y of the lower end of the spring as a function of t is given above, where $y = 0$ when the spring was initially unstretched.

16. At which of the following times is the upward velocity of the object the greatest?

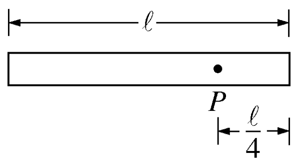
(A) 0.00 s
(B) 0.25 s
(C) 0.50 s
(D) 0.75 s
(E) 1.00 s

17. What is the spring constant of the spring?

(A) 16 N/m
(B) 20 N/m
(C) 32 N/m
(D) 40 N/m
(E) 64 N/m

18. Identical net forces act for the same length of time on two different spherical masses. Which of the following describes the change in linear momentum of the smaller mass compared to that of the larger mass?

(A) It is smaller than the change in linear momentum of the larger mass but not zero.
(B) It is larger than the change in linear momentum of the larger mass.
(C) It is equal to the change in linear momentum of the larger mass.
(D) It is zero.
(E) It depends on the relative diameters of the two masses.



19. The uniform thin rod shown above has mass m and length ℓ. The moment of inertia of the rod about an axis through its center and perpendicular to the rod is $(1/12)m\ell^2$. What is the moment of inertia of the rod about an axis perpendicular to the rod and passing through point P, which is halfway between the center and the end of the rod?

(A) $\frac{1}{3}m\ell^2$

(B) $\frac{1}{6}m\ell^2$

(C) $\frac{1}{12}m\ell^2$

(D) $\frac{1}{48}m\ell^2$

(E) $\frac{7}{48}m\ell^2$

20. A certain one-dimensional conservative force is given as a function of x by the expression $F = -kx^3$, where F is in newtons and x is in meters. A possible potential energy function U for this force is

(A) $U = -\frac{1}{2}kx^2$

(B) $U = \frac{1}{2}kx^2$

(C) $U = -\frac{1}{4}kx^4$

(D) $U = \frac{1}{4}kx^4$

(E) $U = -3kx^2$

21. Which of the following is a differential equation that correctly describes Newton's second law for a simple harmonic oscillator of mass m and restoring force constant k ?

(A) $kx = m\frac{d^2x}{dt^2}$

(B) $-kx = m\frac{d^2x}{dt^2}$

(C) $-kv = m\frac{dv}{dt}$

(D) $kx = m\frac{dx}{dt}$

(E) $mg - kv = m\frac{dv}{dt}$

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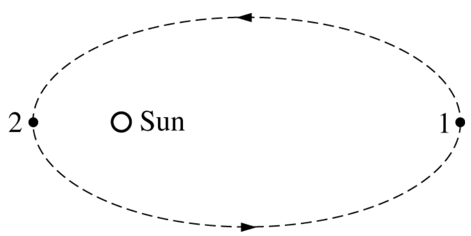
Questions 22-24



Note: Figure not drawn to scale.

The elliptical orbit of a comet is shown above. Positions 1 and 2 are, respectively, the farthest and nearest positions to the Sun, and at position 1 the distance from the comet to the Sun is 10 times that at position 2.

22. At position 2, the comet's kinetic energy is

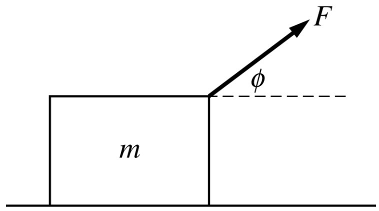
(A) the same as at position 1
(B) less than at position 1
(C) at its maximum value for the orbit
(D) at its minimum value for the orbit, but greater than zero
(E) equal to zero

23. What is the ratio υ_1/υ_2 of the speed of the comet at position 1 to the speed at position 2 ?

(A) 1/100
(B) 1/10
(C) 1
(D) 10
(E) 100

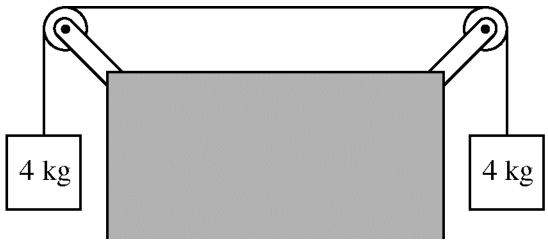
24. What is the ratio F_1/F_2 of the force on the comet at position 1 to the force on the comet at position 2 ?

(A) 1/100
(B) 1/10
(C) 1
(D) 10
(E) 100



25. A block of mass m is pulled across a rough surface, as shown above. The coefficient of friction between the block and the surface is μ_k. The force F that pulls the block is exerted at the angle ϕ shown. Which of the following is an expression for the magnitude of the frictional force on the block if it is moving at constant speed?

(A) $\mu_k mg$
(B) $\mu_k F\cos\phi$
(C) $\mu_k(F\sin\phi + mg)$
(D) $\mu_k(F\sin\phi - mg)$
(E) $\mu_k(mg - F\sin\phi)$



26. Two 4 kg blocks hang from a rope that passes over two frictionless pulleys, as shown in the figure above. What is the tension in the horizontal portion of the rope if the blocks are not moving and the rope and the two pulleys have negligible mass?

(A) 4 N
(B) 8 N
(C) 20 N
(D) 40 N
(E) 80 N

GO ON TO THE NEXT PAGE.

27. A person throws a ball of mass 0.20 kg. The ball starts from rest, accelerates horizontally and uniformly through a distance of 0.90 m, and leaves the person's hand at 30 m/s. The average horizontal force applied to the ball by the person's hand is

(A) 3.3 N
(B) 16.7 N
(C) 81 N
(D) 100 N
(E) 200 N

28. A railroad car of mass 1500 kg rolls to the right at 4 m/s and collides with another railroad car of mass 3000 kg that is rolling to the left at 3 m/s. The cars stick together. Their speed immediately after the collision is

(A) $\frac{2}{3}$ m/s

(B) 1 m/s

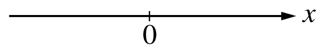
(C) $\frac{5}{3}$ m/s

(D) $\frac{10}{3}$ m/s

(E) 7 m/s

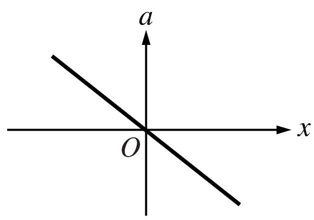
29. A meterstick of negligible mass is placed on a fulcrum at the 0.4 m mark, with a 1 kg mass hung at the zero mark and a 0.5 kg mass hung at the 1.0 m mark. The meterstick is held horizontal and released. Immediately after release, the magnitude of the net torque on the meterstick about the fulcrum is most nearly

(A) 1 N•m
(B) 2 N•m
(C) 2.5 N•m
(D) 7 N•m
(E) 7.5 N•m

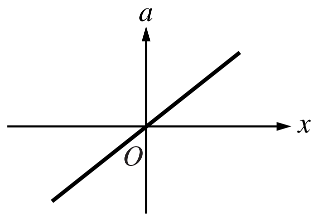


30. An object undergoes simple harmonic motion along the x-axis shown above, where $x = 0$ is the object's equilibrium position. Which of the following graphs best shows the relationship between the object's acceleration a and its displacement x from equilibrium? (Assume positive a to be acceleration directed to the right.)

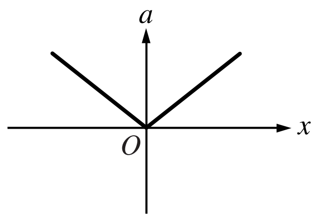
(A)



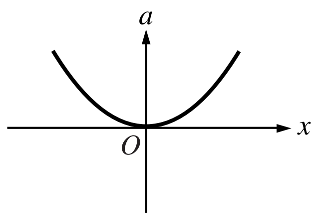
(B)



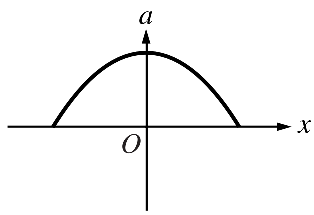
(C)



(D)



(E)



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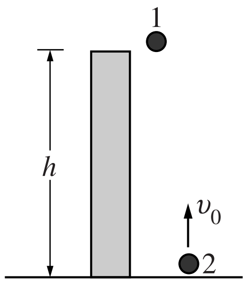


31. Ball 1 is dropped from rest at time $t = 0$ from a tower of height h, as shown above. At the same instant, ball 2 is launched upward from the ground with initial speed v_0. If air resistance is negligible, at what time t will the two balls pass each other?

(A) $\frac{1}{4}\frac{h}{v_0}$

(B) $\frac{1}{2}\frac{h}{v_0}$

(C) $\frac{h}{v_0}$

(D) $2\frac{h}{v_0}$

(E) $4\frac{h}{v_0}$

32. Suppose that the potential energy of a particle constrained to move along the x-axis can be described by the function $U(x) = \frac{1}{2}kx^2 - \alpha x$, where both k and α are positive constants. Stable equilibrium points, about which the particle oscillates, are located at

(A) $x = 0$ only

(B) $x = \frac{\alpha}{k}$ only

(C) $x = \frac{2\alpha}{k}$ only

(D) $x = 0$ and $\frac{\alpha}{k}$

(E) $x = 0$ and $\frac{2\alpha}{k}$

33. A ball of mass m falls vertically, hits the floor with a speed v_i, and rebounds with a speed v_f. What is the magnitude of the impulse exerted on the ball by the floor?

(A) $2m(v_f - v_i)$

(B) $m(v_f - v_i)$

(C) $m(v_f + v_i)$

(D) mv_i

(E) mv_f

Questions 34-35

A particle moves in a circle in such a way that the x- and y-coordinates of its motion, given in meters as functions of time t in seconds, are:

$$x = 5\cos(3t)$$
$$y = 5\sin(3t).$$

34. What is the radius of the circle?

(A) $\frac{5}{3}$ m

(B) $\frac{5}{2}$ m

(C) 5 m

(D) 10 m

(E) 15 m

35. Which of the following is true of the speed of the particle?

(A) It is always equal to 5 m/s.
(B) It is always equal to 15 m/s.
(C) It oscillates with a range of 0 to 5 m/s.
(D) It oscillates with a range of 0 to 15 m/s.
(E) It oscillates with a range of 5 to 15 m/s.

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**

Section II: Free-Response Questions

This is the free-response section of the 2012 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

2012

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 4IBP-S2
80

TABLE OF INFORMATION DEVELOPED FOR 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, $N_0 = 6.02 \times 10^{23}\ \text{mol}^{-1}$	Universal gravitational constant, $G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2$
Universal gas constant, $R = 8.31$ J/(mol•K)	Acceleration due to gravity at Earth's surface, $g = 9.8\ \text{m/s}^2$
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,	$h = 6.63 \times 10^{-34}\ \text{J}\cdot\text{s} = 4.14 \times 10^{-15}\ \text{eV}\cdot\text{s}$
	$hc = 1.99 \times 10^{-25}\ \text{J}\cdot\text{m} = 1.24 \times 10^{3}\ \text{eV}\cdot\text{nm}$
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$
Magnetic constant,	$k' = \mu_0/4\pi = 1 \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$
1 atmosphere pressure,	$1\text{ atm} = 1.0 \times 10^{5}\ \text{N/m}^2 = 1.0 \times 10^{5}$ 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 DEVELOPED FOR 2012

MECHANICS

$\upsilon = \upsilon_0 + at$

$x = x_0 + \upsilon_0 t + \frac{1}{2}at^2$

$\upsilon^2 = \upsilon_0^2 + 2a(x - x_0)$

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

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

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

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

$F_{fric} \leq \mu N$

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

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

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

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

$\Delta U_g = mgh$

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

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

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

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

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

$\upsilon = r\omega$

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

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

$\omega = \omega_0 + \alpha t$

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

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
υ = 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

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

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

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

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

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

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

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

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

$C_p = \sum_i C_i$

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

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

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

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

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

$I = Nev_d A$

$V = IR$

$R_s = \sum_i R_i$

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

$P = IV$

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

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
υ = velocity or speed
ρ = resistivity
ϕ_m = magnetic flux
κ = dielectric constant

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

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

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

$B_s = \mu_0 nI$

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

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

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

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

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

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

$S = 4\pi r^2$

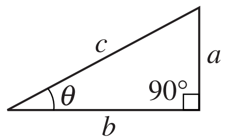
Right Triangle

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

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

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

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



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

CALCULUS

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

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

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

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

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

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

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

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

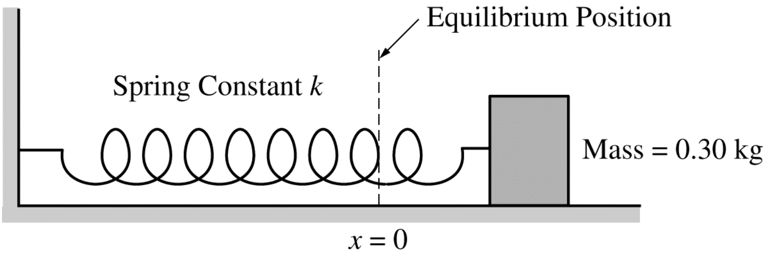
$$\int \frac{dx}{x} = \ln|x|$$

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

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

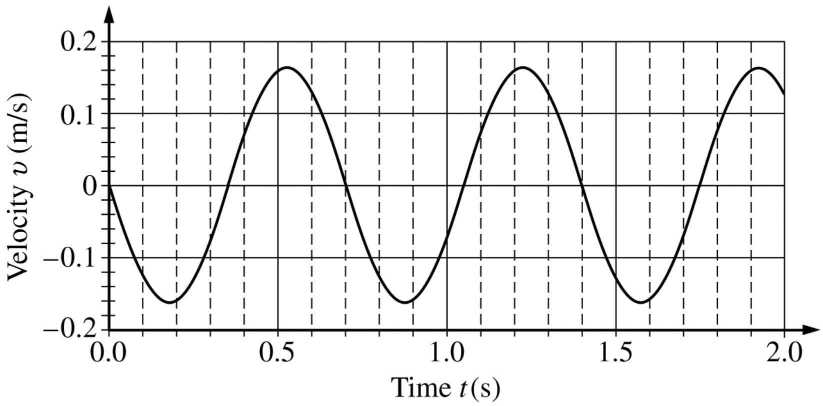
PHYSICS C: MECHANICS
SECTION II
Time—45 minutes
3 Questions

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 0.30 kg is placed on a frictionless table and is attached to one end of a horizontal spring of spring constant k, as shown above. The other end of the spring is attached to a fixed wall. The block is set into oscillatory motion by stretching the spring and releasing the block from rest at time $t = 0$. A motion detector is used to record the position of the block as it oscillates. The resulting graph of velocity v versus time t is shown below. The positive direction for all quantities is to the right.



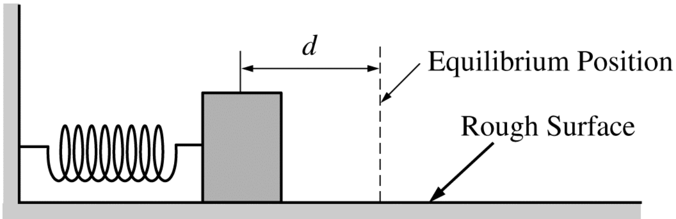
(a) Determine the equation for $v(t)$, including numerical values for all constants.

(b) Given that the equilibrium position is at $x = 0$, determine the equation for $x(t)$, including numerical values for all constants.

GO ON TO THE NEXT PAGE.

(c) Calculate the value of k.

Experiment 2. The block and spring arrangement is now placed on a rough surface, as shown below. The block is displaced so that the spring is compressed a distance d and released from rest.

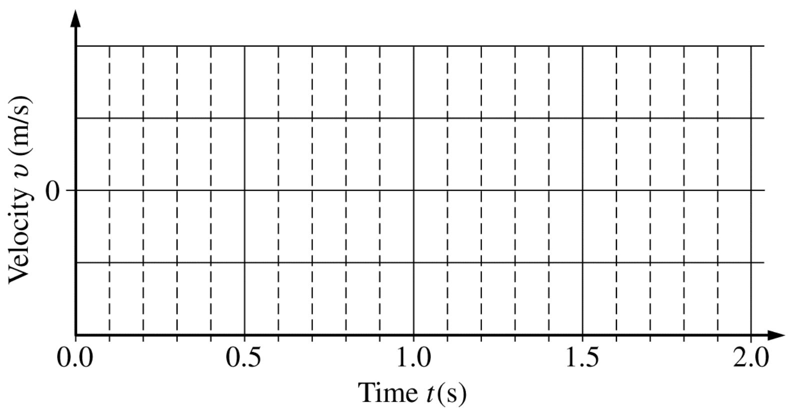


(d) On the dots below that represent the block, draw and label the forces (not components) that act on the block when the spring is compressed a distance $x = d/2$ and the block is moving in the direction indicated below each dot.

Toward
the equilibrium position

Away from
the equilibrium position

(e) Draw a sketch of v versus t in this case. Assume that there is a negligible change in the period and that the positive direction is still to the right.



Mech. 2.

You are to perform an experiment investigating the conservation of mechanical energy involving a transformation from initial gravitational potential energy to translational kinetic energy.

(a) You are given the equipment listed below, all the supports required to hold the equipment, and a lab table. On the list below, indicate each piece of equipment you would use by checking the line next to each item.

____ Track	____ Meterstick	____ Set of objects of different masses
____ Cart	____ Electronic balance	____ Lightweight low-friction pulley
____ String	____ Stopwatch	

(b) Outline a procedure for performing the experiment. Include a diagram of your experimental setup. Label the equipment in your diagram. Also include a description of the measurements you would make and a symbol for each measurement.

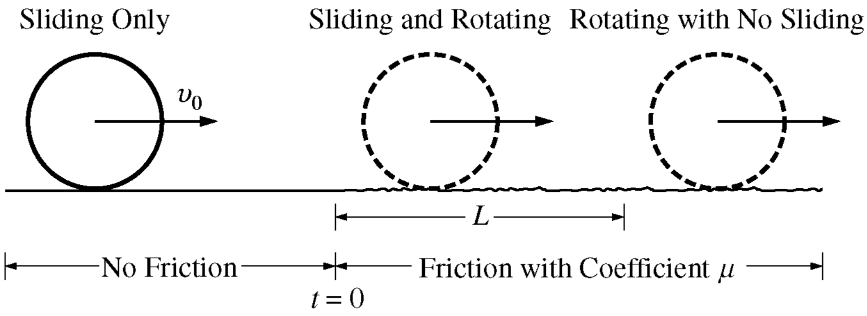
GO ON TO THE NEXT PAGE.

(c) Give a detailed account of the calculations of gravitational potential energy and translational kinetic energy both before and after the transformation, in terms of the quantities measured in part (b).

(d) After your first trial, your calculations show that the energy increased during the experiment. Assuming you made no mathematical errors, give a reasonable explanation for this result.

(e) On all other trials, your calculations show that the energy decreased during the experiment. Assuming you made no mathematical errors, give a reasonable physical explanation for the fact that the average energy you determined decreased. Include references to conservative and nonconservative forces, as appropriate.

GO ON TO THE NEXT PAGE.



Mech. 3.

A ring of mass M, radius R, and rotational inertia MR^2 is initially sliding on a frictionless surface at constant velocity v_0 to the right, as shown above. At time $t = 0$ it encounters a surface with coefficient of friction μ and begins sliding and rotating. After traveling a distance L, the ring begins rolling without sliding. Express all answers to the following in terms of M, R, v_0, μ, and fundamental constants, as appropriate.

(a) Starting from Newton's second law in either translational or rotational form, as appropriate, derive a differential equation that can be used to solve for the magnitude of the following as the ring is sliding and rotating.

i. The linear velocity v of the ring as a function of time t

ii. The angular velocity ω of the ring as a function of time t

(b) Derive an expression for the magnitude of the following as the ring is sliding and rotating.

i. The linear velocity v of the ring as a function of time t

ii. The angular velocity ω of the ring as a function of time t

GO ON TO THE NEXT PAGE.

(c) Derive an expression for the time it takes the ring to travel the distance L.

(d) Derive an expression for the magnitude of the velocity of the ring immediately after it has traveled the distance L.

(e) Derive an expression for the distance L.

GO ON TO THE NEXT PAGE.

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 AND 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 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 C: Mechanics
Practice Exam, Section I

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

Free-Response Scoring Guidelines

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

General Notes About 2012 AP Physics Scoring Guidelines

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

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

3. Implicit statements of concepts normally receive credit. For example, if the use of an equation expressing a particular concept is worth 1 point, and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression, it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics Exam equation sheets. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections — Student Presentation" in the *AP Physics Course Description*.

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

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

Question 1

15 points total	**Distribution of points**

(a) 4 points

For writing a correct trigonometric equation for velocity as a function of time, including the negative sign — 1 point

$\upsilon(t) = -\upsilon_{\max}\sin(\omega t) = -\upsilon_{\max}\sin(2\pi t/T)$

For using $\omega = 2\pi f$ or $\omega = \dfrac{2\pi}{T}$ to solve for ω — 1 point

For using the correct period of 0.70 s from the graph — 1 point

$\omega = \dfrac{2\pi}{0.70\text{s}} = 9.0 \text{ rad/s}$

For using the correct value of the maximum speed from the graph (acceptable range of values for $\upsilon_{\max}$: 0.15 m/s to 0.17 m/s) — 1 point

$\upsilon(t) = (-0.16)\sin(9.0t)$

<u>Note</u>: One point is deducted if incorrect phase shift ϕ is used. Full credit is awarded for a correct answer with no work shown. Students are also given credit if the value of k from part (c) is used to calculate ω using $\omega = \sqrt{k/m}$.

(b) 2 points

Take the integral of the velocity determined in part (a)

$x(t) = \int \upsilon(t)dt = \int (-0.16 \text{ m/s})\sin((9.0 \text{ rad/s})t)dt$

For a correct trigonometric expression consistent with integrating the answer from part (a) — 1 point

For a correct $x_{\max}$ consistent with the integrating the answer from part (a) — 1 point

$x_{\max} = (0.16 \text{ m/s})/(9.0 \text{ rad/s}) = 0.018 \text{ m}$

$x(t) = (0.018)\cos(9.0t)$

Question 1 (continued)

Distribution of points

(b) continued

Alternate solution — *Alternate points*

For solving for a maximum displacement consistent with the answer from part (a) — *1 point*

$$\upsilon_{max} = x_{max}\omega$$

$$x_{max} = \frac{\upsilon_{max}}{\omega} = \frac{(0.16\ \text{m/s})}{(9.0\ \text{rad/s})}$$

$$x_{max} = 0.018\ \text{m}$$

For a correct trigonometric expression consistent with the answer from part (a) — *1 point*

$$x(t) = (0.018)\cos(9.0t)$$

Note: Full credit is awarded for a correct answer with no work shown. One earned point is deducted for incorrect initial conditions (e.g., subtracting a constant from the cosine function).

(c) 2 points

For a correct relationship between the period and the spring constant — 1 point

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

For substituting correct values from previous parts into a correct expression — 1 point

$$k = \frac{4\pi^2 m}{T^2} = \frac{\left(4\pi^2\right)(0.30\ \text{kg})}{(0.70\ \text{s})^2}$$

$$k = 24\ \text{N/m}$$

Alternate solution #1 — *Alternate points*

For a correct expression relating angular frequency and the spring constant — *1 point*

$$\omega = \sqrt{\frac{k}{m}}$$

For substituting correct values from previous parts into a correct expression — *1 point*

$$k = m\omega^2 = (0.30\ \text{kg})(9.0\ \text{rad/s})^2$$

$$k = 24\ \text{N/m}$$

Question 1 (continued)

Distribution of points

(c) continued

Alternate solution #2 — *Alternate points*

For a correct statement of the conservation of energy, applied to the position of maximum displacement and the equilibrium position — *1 point*

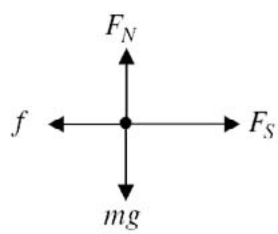
$$\frac{1}{2}kx_{max}^2 = \frac{1}{2}mv_{max}^2$$

For substituting correct values from previous parts into a correct expression — *1 point*

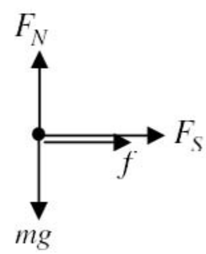
$$k = \frac{mv_{max}^2}{x_{max}^2} = \frac{(0.30\ \text{kg})(0.16\ \text{m/s})^2}{(0.018\ \text{m})^2}$$

$k = 24\ \text{N/m}$

(d) 4 points



Toward the equilibrium position



Away from the equilibrium position

For drawing and labeling F_N and mg correctly on both diagrams — 1 point

On diagram of the block moving toward the equilibrium position:

- For a correctly drawn and labeled spring force to the right — 1 point
- For a correctly drawn and labeled friction force to the left — 1 point

On diagram of the block moving away from the equilibrium position:

- For a correctly drawn and labeled spring force and friction force to the right — 1 point

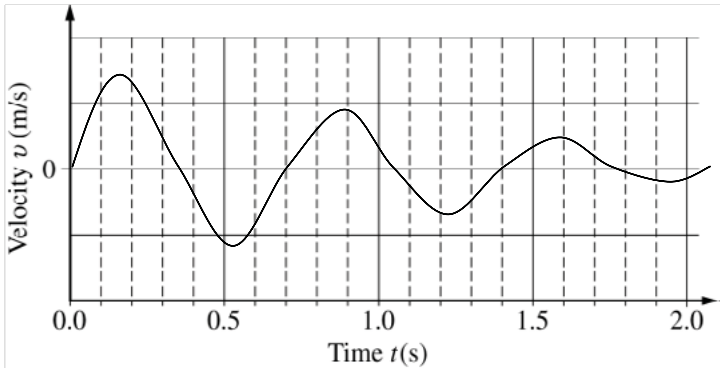
Notes

- Length of vectors is not considered, only direction.
- There is a 1-point maximum deduction for any vectors not touching (or at least almost touching) the dot or for any extraneous forces.Vectors can be drawn from the dot outward OR toward the dot, pointing inward and touching the dot.

Question 1 (continued)

Distribution of points

(e) 3 points



For a graph passing through equilibrium at 0.35 s intervals	1 point
For a graph displaying damped oscillations	1 point
For a graph that starts at zero with an increasing positive velocity	1 point

Question 2

15 points total | **Distribution of points**

(a) 1 point

For choosing the meterstick and stopwatch, regardless of what else is checked — 1 point

(b) 4 points

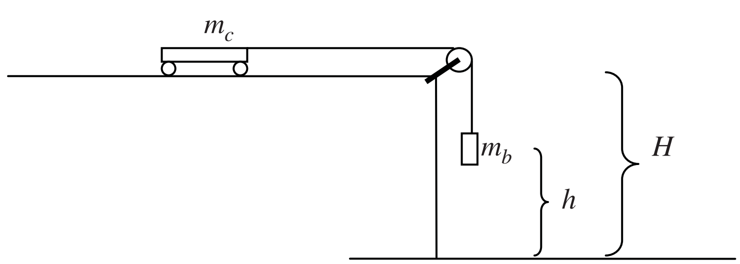
For a procedure that indicates the height needed to calculate gravitational potential energy — 1 point

For a procedure that indicates distance and time measurements to calculate velocity — 1 point

For a diagram and a clear indication of the height measurement — 1 point

For a diagram and a clear indication of the distance measurement — 1 point

<u>Example #1</u>



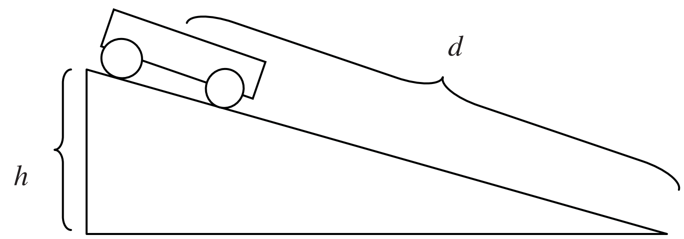
- Use the electronic balance to determine the mass m_c of the cart and the mass m_b of one object.
- Attach the object to the cart using the string.
- Place the cart on the track and hang the object so that the string passes through the pulley.
- Allow the object to fall a distance h from its initial position to the floor, using the meterstick to measure the distance fallen.
- Use the stopwatch to measure the time t it takes the object to fall the distance h.
- Measure the height H of the table.

Question 2 (continued)

Distribution of points

(b) continued

Example #2



- Use the electronic balance to determine the mass m of the cart.
- Set the track at an incline, and measure the height h of the incline.
- Place the cart at the top of the incline, and release from rest.
- Using the stopwatch, measure the time t it takes for the cart to move down the incline.
- Measure the distance d that the cart moves down the incline.

(c) 6 points

For a clear indication of the initial potential energy of the system	1 point
For a clear indication of the final potential energy of the system	1 point
For a clear indication of the initial kinetic energy of the system	1 point
For a clear indication of the final kinetic energy of the system	1 point
For a correct calculation of the instantaneous velocity of the system	2 points

Example #1

Initial gravitational potential energy: $U_{g0} = m_c gH + m_b gh$

Final gravitational potential energy: $U_{gf} = m_c gH$

Initial kinetic energy: $K_0 = 0$

Final kinetic energy: $K_f = \frac{1}{2}(m_c + m_b)v_f^2$

Acceleration is constant, so $d = \frac{1}{2}(v_0 + v_f)t$, where d is the distance along the track.

$$v_f = \frac{2h}{t}$$

Question 2 (continued)

Distribution of points

(c) continued

Example #2

Initial gravitational potential energy: $U_{g0} = mgh$

Final gravitational potential energy $U_{gf} = 0$

Initial kinetic energy $K_0 = 0$

Final kinetic energy $K_f = \frac{1}{2}mv_f^2$

Acceleration is constant, so $d = \frac{1}{2}\left(v_0 + v_f\right)t$.

$v_f = \frac{2d}{t}$

(d) 2 points

For identifying a reasonable cause for the increase in energy	1 point
For a reasonable explanation related to the cause identified	1 point

Example
An unintentional push was applied to the cart, thus increasing the initial energy.

(e) 2 points

For identifying a reasonable cause for the decrease in energy related to the nonconservative forces acting on the system	1 point
For a reasonable explanation related to the cause identified	1 point

Example
Friction acting on the object decreases the speed, thereby decreasing the energy.

Question 3

15 points total | **Distribution of points**

(a)

i. 3 points

For starting with Newton's second law for translation, with friction as the net force — 1 point

$\Sigma F = -f = Ma$

For a correct expression for the frictional force — 1 point

$f = \mu Mg$

For indicating that linear acceleration is the time derivative of velocity — 1 point

$a = \dfrac{d\upsilon}{dt}$

$\dfrac{d\upsilon}{dt} = -\mu g$

ii. 3 points

For starting with Newton's second law for rotation, with a correct substitution for the rotational inertia — 1 point

$\tau = MR^2\alpha$

For a correct expression for the torque, using the frictional force — 1 point

$\tau = \mu MgR$

For indicating that the angular acceleration is the time derivative of the angular velocity — 1 point

$\alpha = \dfrac{d\omega}{dt}$

$\dfrac{d\omega}{dt} = \dfrac{\mu g}{R}$

(b)

i. 2 points

For setting up the integral of the function determined in part (a)-i — 1 point

$\int_{\upsilon_0}^{\upsilon} d\upsilon = -\int_0^t \mu g dt$

For the correct answer — 1 point

$\upsilon = \upsilon_0 - \mu gt$

Alternate solution — *Alternate points*

For a clear substitution of the acceleration from part (a)-i into the kinematics equation — *1 point*

$a = -\mu g$

$\upsilon = \upsilon_0 + at$

For the correct answer — *1 point*

$\upsilon = \upsilon_0 - \mu gt$

Question 3 (continued)

	Distribution of points
(b) continued	
ii. 2 points	
For setting up the integral of the function determined in part (a)-ii $\int_0^{\omega} d\omega = \int_0^{t} (\mu g/R)\,dt$	1 point
For the correct answer $\omega = \mu g t/R$	1 point
Alternate solution	*Alternate points*
For a clear substitution of the angular acceleration from part (a)-ii into the correct rotational kinematics equation $\alpha = \dfrac{\mu g}{R}$ $\omega = \omega_0 + \alpha t$	*1 point*
For the correct answer $\omega = \mu g t/R$	*1 point*
(c) 2 points	
For indicating that the linear speed is equal to $R\omega$ when the slipping stops $v = R\omega$ $v_0 - \mu g t = R\left(\dfrac{\mu g t}{R}\right)$	1 point
For the correct answer $t = \dfrac{v_0}{2\mu g}$	1 point
(d) 1 point	
For substituting the time found in part (c) into a correct kinematics equation $v = v_0 - \mu g\left(\dfrac{v_0}{2\mu g}\right)$ $v = v_0/2$	1 point

Question 3 (continued)

Distribution of points

(e) 2 points

For setting up the integral of the velocity function determined in part (b)-i — 1 point

$L = \int_0^t (\upsilon_0 - \upsilon g t)\,dt$

For the correct answer, with correct supporting work — 1 point

$L = \left[\upsilon_0 t - \frac{1}{2}\mu g t^2\right]_0^{\frac{\upsilon_0}{2\mu g}}$

$L = \frac{3\upsilon_0^2}{8\mu g}$

Alternate solution #1 — *Alternate points*

For substituting the velocity from part (d) and the acceleration from part (a)-i into a correct equation that solves for L — *1 point*

$\upsilon^2 = \upsilon_0^2 + 2a\Delta x$

$\left(\frac{\upsilon_0}{2}\right)^2 = \upsilon_0^2 + 2(-\mu g)L$

For the correct answer, with correct supporting work — *1 point*

$L = \frac{3\upsilon_0^2}{8\mu g}$

Alternate solution #2 — *Alternate points*

For substituting the velocity from part (d) and the acceleration from part (a)-i into a correct equation that solves for L — *1 point*

Note: The time determined in part (c) must also be substituted.

$\Delta x = \upsilon_0 t + \frac{1}{2}at^2$

$L = \upsilon_0\left(\frac{\upsilon_0}{2\mu g}\right) + \frac{1}{2}(-\mu g)\left(\frac{\upsilon_0}{2\mu g}\right)^2$

For the correct answer, with correct supporting work — *1 point*

$L = \frac{3\upsilon_0^2}{8\mu g}$

Scoring Worksheet

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

2012 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 ____________ × 1.0000 = ______________
(out of 15) (Do not round)

Question 2 ____________ × 1.0000 = ______________
(out of 15) (Do not round)

Question 3 ____________ × 1.0000 = ______________
(out of 15) (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
54-90	5
42-53	4
33-41	3
25-32	2
0-24	1

AP Physics C: Mechanics

The College Board