CollegeBoard

AP Physics C: Electricity and Magnetism Practice Exam

From the 2012 Administration

Contents

Note: 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: Electricity and Magnetism 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 students are taking only Electricity and Magnetism, and tell them to report to the testing room at approximately 2 p.m. (1 p.m. in Alaska). You should instruct them to wait quietly outside the room until told to come in, since students taking Mechanics may not have been dismissed yet. If all students are taking Electricity and Magnetism only, you must not begin the exam before 2 p.m.

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: Electricity and Magnetism 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: Electricity and Magnetism 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 of 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. You may keep it only if you are not taking any other AP Exams this year. If you have no other AP Exams to take, place your Student Pack under your chair now. . . .

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 the exam booklet. 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 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, say:

> **Please remember to take your AP number card with you.**

Then say:

> **You are now dismissed.**

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.

GO ON TO THE NEXT PAGE.

GO ON TO THE NEXT PAGE.

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.

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 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 –

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	PM
6	12
7	1
8	2
9	3
10	4
11	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: 0 1 2 3 / 0 1 2 3 4 5 6 7 8 9
Year: 0 1 2 3 4 5 6 7 8 9

J. SEX

- Female
- Male

K. CURRENT GRADE LEVEL

- Pre-9th
- 9th
- 10th
- 11th
- 12th
- Post-12th

L. SOCIAL SECURITY NUMBER (Optional)

0 1 2 3 4 5 6 7 8 9

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	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ
2	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	5	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ
3	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	6	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ

7	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ
8	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ
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.)

CITY

ZIP OR POSTAL CODE

COUNTRY CODE

STATE

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

U. AREA CODE AND PHONE NUMBER

INTERNATIONAL PHONE

V. SCHOOL YOU ATTEND

SCHOOL CODE

School Name

City

State

Country

W. 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

X. FOR STUDENTS OUTSIDE THE UNITED STATES ONLY

If the address gridded above is not complete enough for delivery of your score report, please fill in this circle and print your complete address below. →

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

Y. 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 *2011-12 Bulletin for AP Students and Parents*.

GO ON TO THE NEXT PAGE.

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.)

PLACE SEAL HERE

AP® Physics C: Electricity and Magnetism 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

Minimum 20% post-consumer waste

PLACE SEAL HERE
DO NOT seal answer sheet inside

Form I
Form Code 4IBP4-S
82

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,	$g = 9.8\ \text{m/s}^2$
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,	$\mu_0 = 4\pi \times 10^{-7}$ (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 on a system.

PHYSICS C: ELECTRICITY AND MAGNETISM

SECTION I

Time—45 minutes

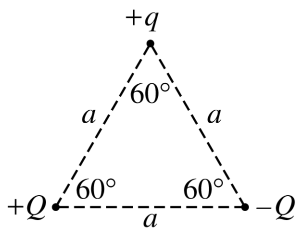
35 Questions

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.

1. A proton moving along the positive x-axis enters an electric field that is directed along the positive y-axis. What is the direction of the electric force acting on the proton after it enters the electric field?

   (A) Along the negative z-axis
   (B) Along the positive z-axis
   (C) Along the negative y-axis
   (D) Along the positive y-axis
   (E) The direction cannot be determined since the magnitude of the electric field is not known.

Questions 2-4



Three particles having charges of $+q$, $+Q$, and $-Q$ are placed at the corners of an equilateral triangle of side a, as shown above.

2. The net force on the particle with charge $+q$ due to the other two charges is in the plane of the page and directed

   (A) vertically upward
   (B) vertically downward
   (C) horizontally to the right
   (D) horizontally to the left
   (E) toward the charge $-Q$

3. The magnitude of the force on the particle with charge $+q$ due to the other two charges is

   (A) $\dfrac{kqQ}{a}$

   (B) $\dfrac{2kqQ}{a}$

   (C) $\dfrac{2kqQ}{a^2}$

   (D) $\dfrac{2kqQ\sin 60°}{a^2}$

   (E) $\dfrac{2kqQ\cos 60°}{a^2}$

4. The potential energy of the particle with charge $+q$ due to the other two charges is

   (A) zero

   (B) $\dfrac{-2kQ}{a}$

   (C) $\dfrac{kqQ}{a}$

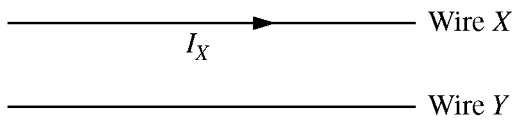
   (D) $\dfrac{2kqQ}{a}$

   (E) $\dfrac{2kqQ}{a^2}$

5. All the following statements about an isolated, solid charged conductor are correct EXCEPT:

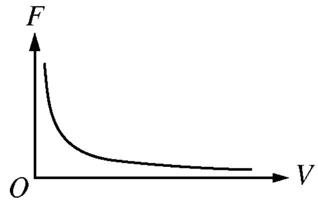
(A) All parts of the conductor are at the same potential.
(B) All excess charge resides on the outer surface.
(C) The net charge enclosed by any surface lying entirely within the conductor must equal zero.
(D) The electric field **E** just outside the conductor is directed parallel to the surface.
(E) The electric field intensity inside the conductor is zero.

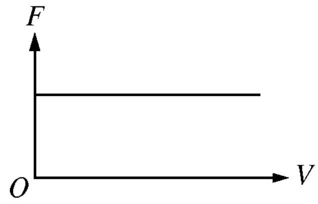
Questions 6-8



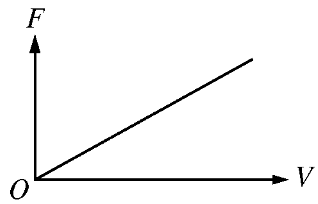
Two long, straight, parallel wires are held fixed, as shown above. A voltage is applied to wire X, creating a current I_X to the right, and the wire experiences a magnetic force of magnitude F_B toward wire Y.

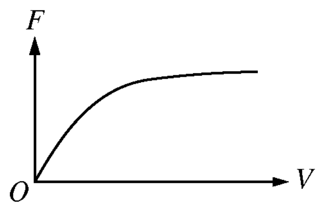
6. Assuming the resistance of wire X is constant, which of the following graphs correctly illustrates the magnitude of the magnetic force F on wire X as a function of the voltage V applied to the wire?

(A)


(B)


(C)


(D)


(E)


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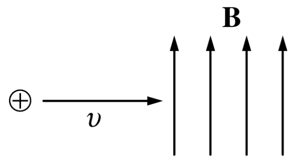
7. Which of the following could be true of wire Y ?

   I. It carries a current in the same direction as the current in wire X.
   II. It experiences a force directed away from wire X.
   III. It experiences a force of different magnitude than the force on wire X.

(A) None
(B) I only
(C) II only
(D) III only
(E) I or II

8. If the distance between the two wires is tripled, what is the magnitude of the new magnetic force exerted on wire X ?

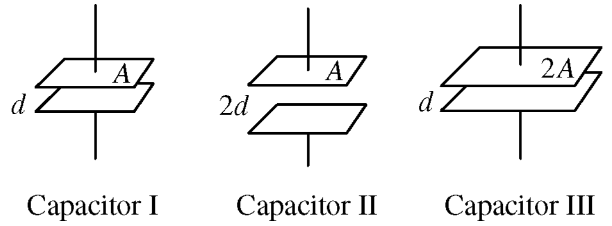
(A) $F_B/9$
(B) $F_B/3$
(C) F_B
(D) $3F_B$
(E) $9F_B$



9. A proton moving to the right at constant speed v enters a region containing uniform magnetic and electric fields and continues to move in a straight line. The magnetic field **B** is directed toward the top of the page, as shown above. The direction of the electric field must be

(A) into the page
(B) out of the page
(C) to the left
(D) toward the top of the page
(E) toward the bottom of the page

Questions 10-11



The plate areas and separations for three capacitors are shown in the diagram above. The space between the plates in each capacitor is filled with air.

10. Suppose all three capacitors have charge $+Q$ on the top plate and charge $-Q$ on the bottom plate. Which of the following is true of the potential difference across the plates of the three capacitors?

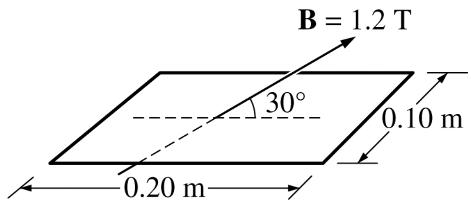
(A) It is greatest for I.
(B) It is greatest for II.
(C) It is greatest for III.
(D) It is the same for II and III and least for I.
(E) It is the same for all three capacitors.

11. Suppose all three capacitors are connected in parallel with a 9 V battery. Which of the following is true of the electric field between the plates?

(A) It is greatest for I.
(B) It is greatest for II.
(C) It is greatest for III.
(D) It is the same for I and III and least for II.
(E) It is the same for I and II and least for III.

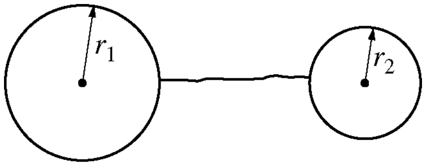
12. The electric potential along an x-axis is given by the expression $V = ax - bx^2$, where a and b are constants. At what point on the x-axis is the electric field zero?

(A) $x = 0$
(B) $x = a/2b$
(C) $x = a/b$
(D) $x = 3a/2b$
(E) At no point



13. A uniform magnetic field **B** of magnitude 1.2 T passes through a rectangular loop of wire, which measures 0.10 m by 0.20 m. The field is oriented 30° with respect to the plane of the loop, as shown above. What is the magnetic flux through the loop?

(A) Zero
(B) 0.012 $T \cdot m^2$
(C) 0.02 $T \cdot m^2$
(D) 0.024 $T \cdot m^2$
(E) 0.048 $T \cdot m^2$



Note: Figure not drawn to scale.

14. A metal sphere with radius r_1 has a total electric charge of magnitude q. An uncharged metal sphere with radius r_2 (with $r_1 > r_2$) is then connected by a wire to the first sphere, as illustrated above. The separation of the spheres is much greater than the radius of either sphere. When equilibrium is reached, the spheres will have

(A) charges on their surfaces of equal magnitude and the same sign
(B) charges on their surfaces of equal magnitude and opposite sign
(C) equal electric fields at their surfaces
(D) equal capacitances
(E) equal electric potentials

15. A negatively charged conductor attracts a second object. The second object could be which of the following?

I. A conductor with positive net charge
II. A conductor with zero net charge
III. An insulator with zero net charge

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

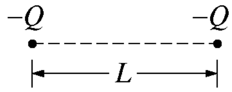
16. Three resistors having resistances of $3\ \Omega$, $6\ \Omega$, and $9\ \Omega$, respectively, are connected in parallel with a 10 V battery. True statements about the circuit include which of the following?

I. The current in the $9\ \Omega$ resistor is three times the current in the $3\ \Omega$ resistor.
II. The potential difference across each resistor is the same.
III. The power dissipated in the $9\ \Omega$ resistor is greater than the power dissipated in either of the other two resistors.

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

17. When two resistors having resistances R_1 and R_2 are connected in parallel, the equivalent resistance of the combination is $10\ \Omega$. Which of the following statements about the resistances is true?

(A) Both R_1 and R_2 are greater than $10\ \Omega$.
(B) Both R_1 and R_2 are equal to $10\ \Omega$.
(C) Both R_1 and R_2 are less than $10\ \Omega$.
(D) The sum of R_1 and R_2 is $10\ \Omega$.
(E) One of the resistances is greater than $10\ \Omega$, and the other is less than $10\ \Omega$.



18. Two particles each with a charge $-Q$ are fixed a distance L apart as shown above. Each particle experiences a net electric force F. A particle with a charge $+q$ is now fixed midway between the original two particles. As a result, the net electric force experienced by each negatively charged particle is reduced to $F/2$. The value of q is

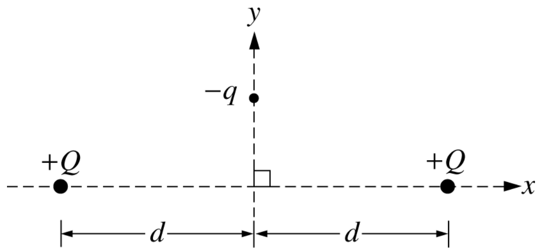
(A) Q

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

(C) $\frac{Q}{4}$

(D) $\frac{Q}{8}$

(E) $\frac{Q}{16}$



Top View

19. Two objects on a horizontal frictionless surface each have charge $+Q$ and each are fixed in place on the x axis at the same distance d from the origin as shown in the figure above. A particle of charge $-q$ constrained to move along the y axis is released from rest. After release, the particle will

(A) stay where it is
(B) exhibit oscillatory motion
(C) move in the direction of increasing y
(D) move in the direction of decreasing y and stop at the origin
(E) move in the direction of decreasing y and keep going to negative infinity

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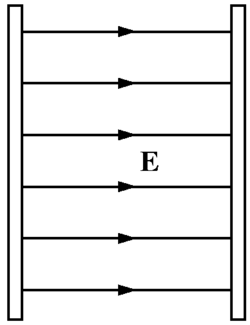


20. A uniform electric field **E** exists between the two large, oppositely charged plates shown above. If the distance between the plates is increased without changing the charges on the plates, which of the following statements can be justified?

(A) The electric field strength decreases.
(B) The electric field strength increases.
(C) The potential difference between the plates decreases.
(D) The potential difference between the plates increases.
(E) There will be no change in either the electric field strength or the potential difference.

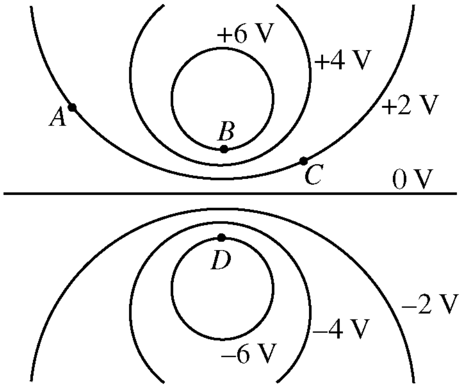
21. When two identical resistors are connected in series to a battery, the total power dissipated is P. When the same two resistors are connected in parallel to the same battery, the total power dissipated is

(A) $\frac{1}{4}P$
(B) $\frac{1}{2}P$
(C) P
(D) $2P$
(E) $4P$

22. A positively charged particle in a uniform magnetic field is moving in a circular path of radius r perpendicular to the field. How much work does the magnetic force F do on the charge for half a revolution?

(A) $\pi r^2 F$
(B) $2\pi r F$
(C) $\pi r F$
(D) $2rF$
(E) Zero

Questions 23-25



The diagram above shows a cross section of equipotential lines produced by a charge distribution. Points *A*, *B*, *C*, and *D* lie in the plane of the page.

23. For which two points can a negatively charged particle be moved from rest at one point to rest at the other with no work being done by the electric field?

(A) *A* and *B*
(B) *A* and *C*
(C) *A* and *D*
(D) *B* and *C*
(E) *B* and *D*

24. A positively charged particle is moved by an external force from rest at one point to rest at another. For which of the following motions would net positive work be required by the external force?

(A) From *A* to *D*
(B) From *B* to *A*
(C) From *C* to *A*
(D) From *C* to *D*
(E) From *D* to *B*

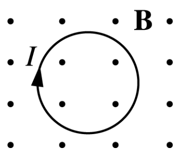
25. The electric potential shown in the diagram could be created by which of the following?

(A) A ring of positive charge
(B) A large sheet of positive charge
(C) Two negative point charges
(D) Two long lines of charge: one positive and one negative
(E) A long line of positive charge and a negative point charge

GO ON TO THE NEXT PAGE.

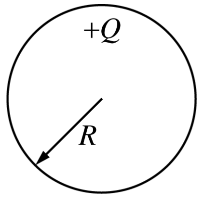
26. A magnetic field perpendicular to the plane of a wire loop is uniform in space but changes with time t in the region of the loop. If the induced emf in the loop increases linearly with time t, then the magnitude of the magnetic field must be proportional to

(A) t^3
(B) t^2
(C) t
(D) t^0 (i.e., constant)
(E) $t^{1/2}$



27. A loop of wire carrying a steady current I is initially at rest perpendicular to a uniform magnetic field of magnitude B, as shown above. The loop is then rotated about a diameter at a constant rate. The torque on the loop is maximum when the loop has rotated, with respect to its initial position, through an angle of

(A) 30°
(B) 45°
(C) 90°
(D) 180°
(E) 360°



28. The solid conducting sphere of radius R shown above has a charge $+Q$ distributed uniformly on its surface. The potential at the center of the solid sphere is

(A) $+\frac{1}{4\pi\epsilon_0}\frac{Q}{R}$

(B) $-\frac{1}{4\pi\epsilon_0}\frac{Q}{R}$

(C) $-\frac{1}{4\pi\epsilon_0}\frac{Q}{R^2}$

(D) zero

(E) undefined

Questions 29-31

A circuit consists of a resistor R, an inductor L, and an open switch S connected in series with a battery. The switch is then closed at time $t = 0$.

29. If the current in the circuit is I at time t, what energy is stored in the circuit in addition to that stored in the battery?

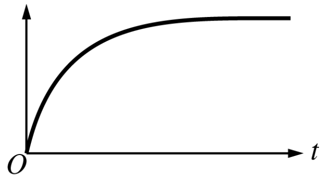
(A) LI

(B) I^2R

(C) $\frac{1}{2}LI^2$

(D) $LI + I^2R$

(E) $\frac{1}{2}LI^2 + I^2R$



30. Which of the following quantities could be represented as a function of time by the graph shown above?

I. The potential difference across the resistor
II. The potential difference across the inductor
III. The current in the circuit

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

31. The change in current when the switch is closed is determined by the inductive time constant τ. If the inductance is doubled and the resistance is halved, the new inductive time constant τ' equals

(A) $\frac{1}{4}\tau$

(B) $\frac{1}{2}\tau$

(C) τ

(D) 2τ

(E) 4τ

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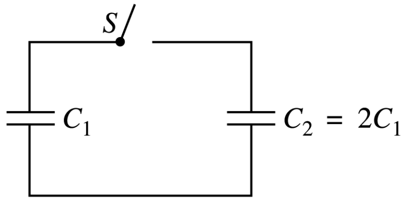
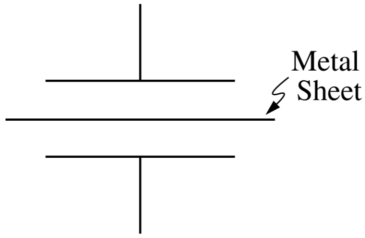


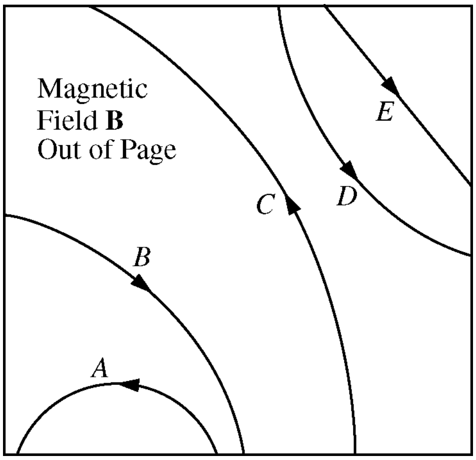
32. A capacitor of capacitance C_1 is charged and then connected to another initially uncharged capacitor of capacitance $C_2 = 2C_1$, as shown above, with the switch S in the open position. When S is closed and the system comes to equilibrium, which of the following is true of the charges on the capacitors and the potential differences across them?

	Charge	Potential Difference
(A)	$Q_1 = \frac{1}{2}Q_2$	$V_1 = \frac{1}{2}V_2$
(B)	$Q_1 = \frac{1}{2}Q_2$	$V_1 = V_2$
(C)	$Q_1 = Q_2$	$V_1 = V_2$
(D)	$Q_1 = Q_2$	$V_1 = \frac{1}{2}V_2$
(E)	$Q_1 = 2Q_2$	$V_1 = V_2$



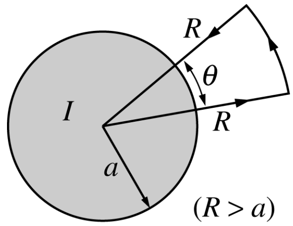
33. An air-gap capacitor originally has capacitance C. If a thin sheet of metal is placed halfway between the plates of the capacitor without touching either plate, as shown above, the effective capacitance is

(A) $4C$
(B) $2C$
(C) C
(D) $C/2$
(E) $C/4$



34. The figure above shows the paths of five particles as they pass through the region inside the box that contains a uniform magnetic field **B** directed out of the page. Which particle has a positive charge?

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



35. A long, straight wire of radius a carries a current I out of the page, which is uniformly distributed over the cross section of the wire. The value of $\oint \mathbf{B} \cdot d\ell$, the line integral of the magnetic field **B** around the wedge-shaped path, equals which of the following?

(A) $\dfrac{\mu_0 \theta I}{2\pi}$

(B) $\dfrac{\mu_0 \theta I}{2\pi^2 a^2}$

(C) $\dfrac{\mu_0 \theta I}{2\pi^2 R^2}$

(D) $\dfrac{\mu_0 I}{\pi a^2}$

(E) $\dfrac{\mu_0 I}{\pi R^2}$

S T O P

END OF ELECTRICITY AND MAGNETISM SECTION I

IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON ELECTRICITY AND MAGNETISM 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**

GO ON TO THE NEXT PAGE.

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: Electricity and Magnetism 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 Devices
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
82

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, $\mu_0 = 4\pi \times 10^{-7}$ (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.

ADVANCED PLACEMENT PHYSICS C EQUATIONS DEVELOPED FOR 2012

MECHANICS

$\upsilon = \upsilon_0 + at$

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

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

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

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

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

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

$F_{fric} \le \mu N$

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

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

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

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

$\Delta U_g = mgh$

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

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

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

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

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

$\upsilon = r\omega$

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

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

$\omega = \omega_0 + \alpha t$

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

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

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

$S = 4\pi r^2$

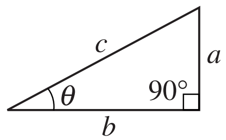
Right Triangle

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

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

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

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



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

CALCULUS

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

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

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

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

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

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

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

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

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

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

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

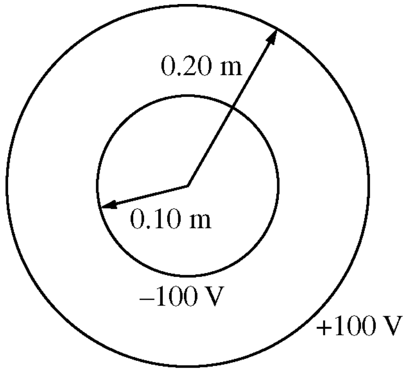
PHYSICS C: ELECTRICITY AND MAGNETISM

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.



E&M. 1.

Two thin, concentric, conducting spherical shells, insulated from each other, have radii of 0.10 m and 0.20 m, as shown above. The inner shell is set at an electric potential of -100 V , and the outer shell is set at an electric potential of +100 V, with each potential defined relative to the conventional reference point. Let Q_i and Q_o represent the net charge on the inner and outer shells, respectively, and let r be the radial distance from the center of the shells. Express all algebraic answers in terms of Q_i , Q_o , r, and fundamental constants, as appropriate.

(a) Using Gauss's Law, derive an algebraic expression for the electric field $E(r)$ for $0.10 \text{ m} < r < 0.20 \text{ m}$.

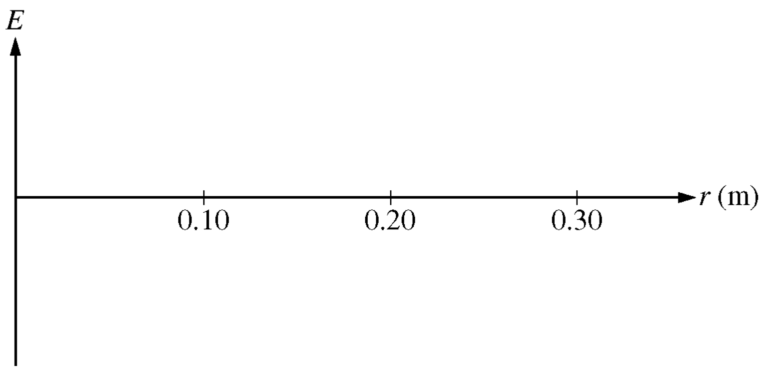
(b) Determine an algebraic expression for the electric field $E(r)$ for $r > 0.20 \text{ m}$.

GO ON TO THE NEXT PAGE.

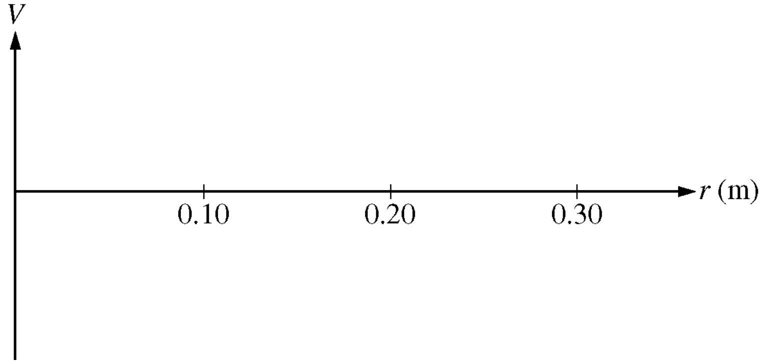
(c) Determine an algebraic expression for the electric potential $V(r)$ for $r > 0.20$ m .

(d) Using the numerical information given, calculate the value of the total charge Q_T on the two spherical shells $(Q_T = Q_i + Q_o)$.

(e) On the axes below, sketch the electric field E as a function of r . Let the positive direction be radially outward.



(f) On the axes below, sketch the electric potential V as a function of r .



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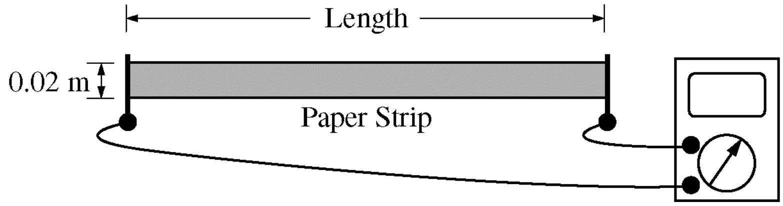
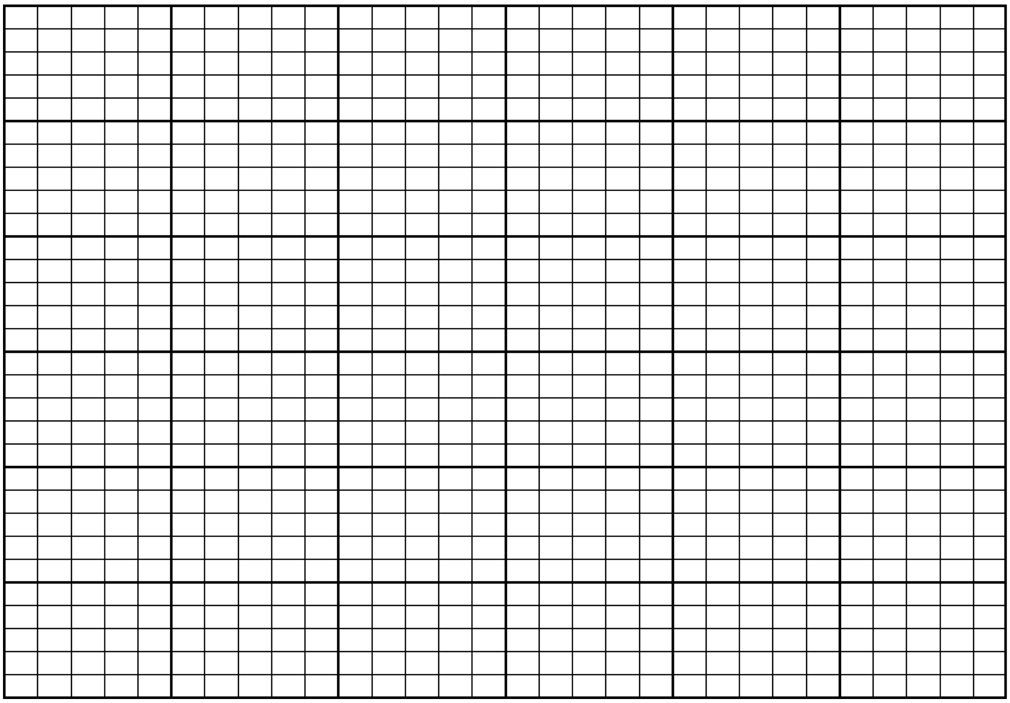


E&M. 2.

A physics student wishes to measure the resistivity of slightly conductive paper that has a thickness of 1.0×10^{-4} m . The student cuts a sheet of the conductive paper into strips of width 0.02 m and varying lengths, making five resistors labeled R1 to R5. Using an ohmmeter, the student measures the resistance of each strip, as shown above. The data are recorded below.

Resistor	R1	R2	R3	R4	R5
Length (m)	0.020	0.040	0.060	0.080	0.100
Resistance (Ω)	80,000	180,000	260,000	370,000	440,000

(a) Use the grid below to plot a linear graph of the data points from which the resistivity of the paper can be determined. Include labels and scales for both axes. Draw the straight line that best represents the data.



(b) Using the graph, calculate the resistivity of the paper.

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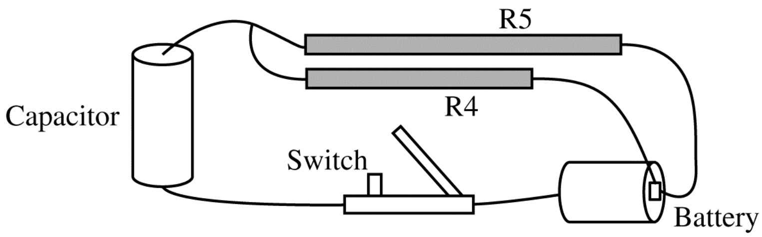
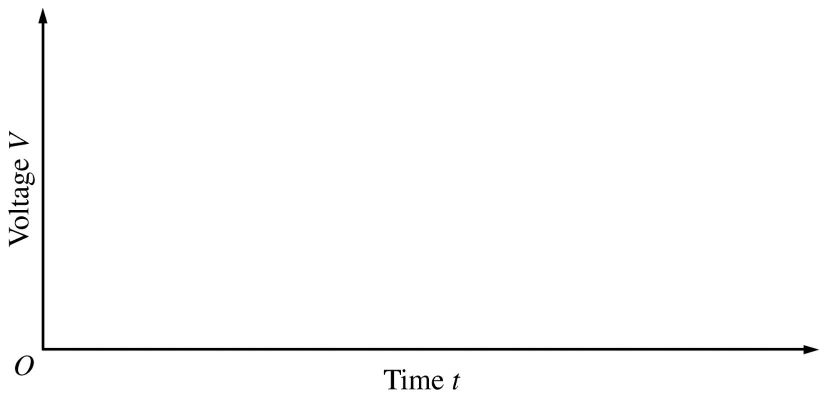
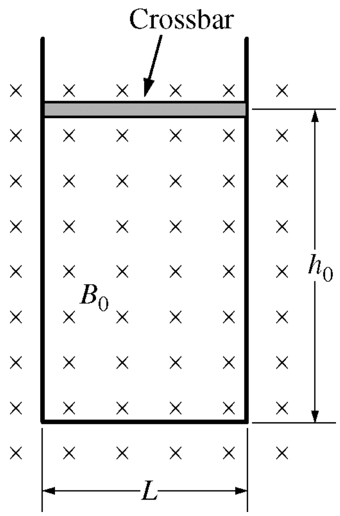


The student uses resistors R4 and R5 to build a circuit using wire, a 1.5 V battery, an uncharged 10 μF capacitor, and an open switch, as shown above.

(c) Calculate the time constant of the circuit.

(d) At time $t = 0$, the student closes the switch. On the axes below, sketch the magnitude of the voltage V_c across the capacitor and the magnitudes of the voltages V_{R4} and V_{R5} across each resistor as functions of time t. Clearly label each curve according to the circuit element it represents. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with values or expressions, as appropriate.





E&M. 3.

A closed loop is made of a U-shaped metal wire of negligible resistance and a movable metal crossbar of resistance R. The crossbar has mass m and length L. It is initially located a distance h_0 from the other end of the loop. The loop is placed vertically in a uniform horizontal magnetic field of magnitude B_0 in the direction shown in the figure above. Express all algebraic answers to the questions below in terms of B_0, L, m, h_0, R, and fundamental constants, as appropriate.

(a) Determine the magnitude of the magnetic flux through the loop when the crossbar is in the position shown.

The crossbar is released from rest and slides with negligible friction down the U-shaped wire without losing electrical contact.

(b) On the figure below, indicate the direction of the current in the crossbar as it falls.

Justify your answer.

(c) Calculate the magnitude of the current in the crossbar as it falls as a function of the crossbar's speed υ.

(d) Derive, but do NOT solve, the differential equation that could be used to determine the speed υ of the crossbar as a function of time *t*.

(e) Determine the terminal speed υ_T of the crossbar.

(f) If the resistance *R* of the crossbar is increased, does the terminal speed increase, decrease, or remain the same?

____ Increases ____ Decreases ____ Remains the same

Give a physical justification for your answer in terms of the forces on the crossbar.

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: Electricity and Magnetism Practice Exam, Section I

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

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 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) 3 points

For an expression of Gauss's Law — 1 point

$$\frac{Q_i}{\epsilon_0} = \oint \mathbf{E} \bullet d\mathbf{A}$$

For a correct intermediate step indicating that the area of the Gaussian surface is $4\pi r^2$ — 1 point

$$\frac{Q_i}{\epsilon_0} = E\left(4\pi r^2\right)$$

For a correct final expression, specifically using Q_i — 1 point

$$E(r) = \frac{1}{4\pi\epsilon_0}\frac{Q_i}{r^2} \quad \text{or} \quad E(r) = \frac{kQ_i}{r^2}$$

(b) 2 points

For indicating that the enclosed charge is the sum of the inner and outer charges — 1 point

$$\frac{Q_i + Q_o}{\epsilon_0} = \oint \mathbf{E} \bullet d\mathbf{A}$$

For a correct expression for the electric field — 1 point

$$E(r) = \frac{1}{4\pi\epsilon_0}\frac{(Q_i + Q_o)}{r^2}$$

<u>Note</u>: The correct expression by itself earns both points.

(c) 2 points

For using the integral definition of potential in terms of electric field — 1 point

$$V(r) - V_\infty = -\int_\infty^r \mathbf{E} \bullet d\mathbf{r}$$

$$V(r) = -\int_\infty^r \frac{1}{4\pi\epsilon_0}\frac{(Q_i + Q_o)}{r^2}dr$$

$$V(r) = -\frac{(Q_i + Q_o)}{4\pi\epsilon_0}\left[-\frac{1}{r}\right]_\infty^r$$

For the correct expression — 1 point

$$V(r) = \frac{1}{4\pi\epsilon_0}\frac{(Q_i + Q_o)}{r}$$

<u>Note</u>: The correct expression by itself earns both points.

Question 1 (continued)

Distribution of points

(c) continued

Alternate solution *Alternate points*

Outside the shells, the charges on each can be treated as point charges at their centers.

For using the concept of summation of point charge potentials *1 point*

$$V(r) = \frac{1}{4\pi\epsilon_0}\sum_j \frac{q_j}{r_j}$$

$$V(r) = \frac{1}{4\pi\epsilon_0}\left(\frac{Q_i}{r} + \frac{Q_o}{r}\right)$$

For the correct expression (the correct expression by itself earns both points) *1 point*

$$V(r) = \frac{1}{4\pi\epsilon_0}\frac{(Q_i + Q_o)}{r}$$

(d) 1 point

The answer from part (c), with $Q_T = Q_i + Q_o$, can be solved for Q_T. Values at the outer shell are then used to determine a numerical value.

For correct work resulting in the correct value, with units 1 point

$$V(r) = \frac{1}{4\pi\epsilon_0}\frac{Q_T}{r},\ r \geq 0.20\,\text{m}$$

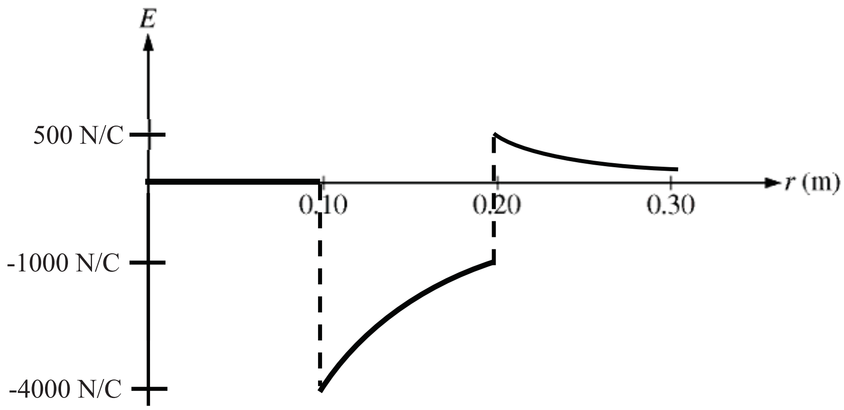
$$Q_T = 4\pi\epsilon_0 rV(r) = \left(\frac{(0.20\text{ m})(100\text{ V})}{\left(9.0\times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2\right)}\right)$$

$$Q_T = 2.2\times 10^{-9}\ \text{C}$$

Question 1 (continued)

Distribution of points

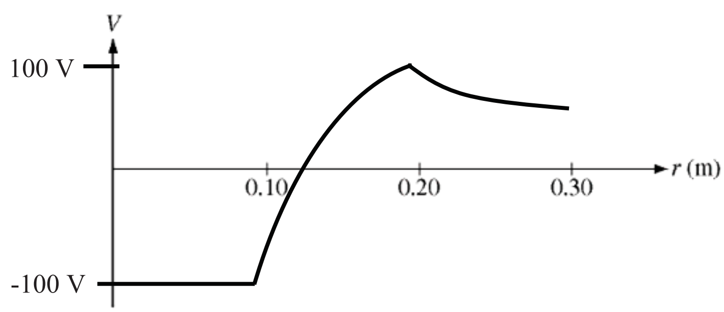
(e) 3 points



For a segment indicating an E-field of 0 for $r < 0.10$ m, explicitly drawn	1 point
For a segment that is concave down and negative for $0.10 \text{ m} < r < 0.20$ m	1 point
For a segment that is concave up and positive for $r > 0.20$ m. The line must not touch or cross the horizontal axis.	1 point

Note: The labels on the vertical axis are not to scale and are not required to receive full credit.

(f) 4 points



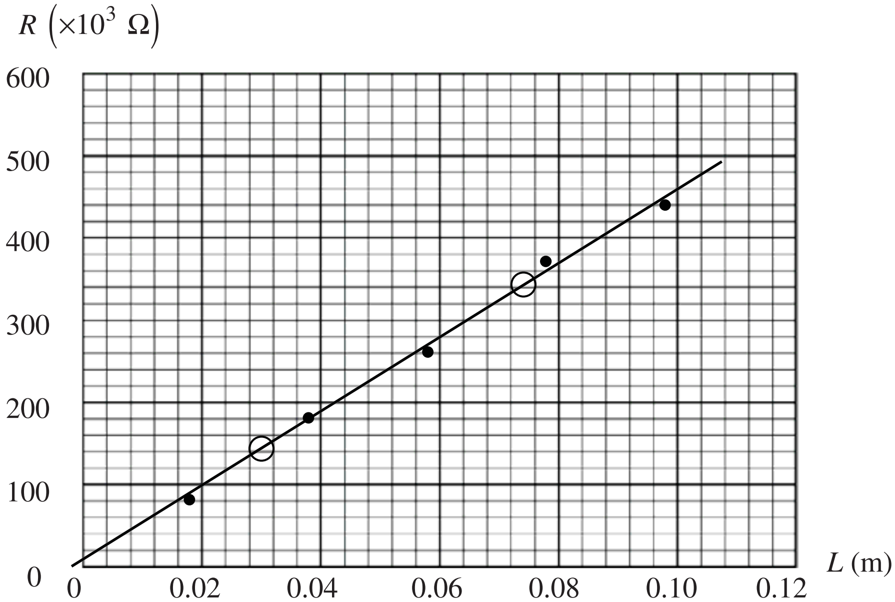
For a continuous set of segments that have slope discontinuities at $r = 0.10$ m and at $r = 0.20$ m	1 point
For a segment indicating a constant negative potential for $r < 0.10$ m	1 point
For a segment that is increasing, concave down, and crosses the r axis, for $0.10 \text{ m} < r < 0.20$ m	1 point
For a segment that is concave up and positive for $r > 0.20$ m. The line must not touch or cross the horizontal axis.	1 point

Note: The labels on the vertical axis are not scored and are not required to receive full credit.

Question 2

15 points total | **Distribution of points**

(a) 4 points



For a correct label on each axis (one including resistance, one including length), that leads to a linear graph — 1 point

For two linear scales, one for each axis, corresponding to the labels and occupying at least three-quarters of each axis — 1 point

For reasonably correctly plotted points according to the scale — 1 point

For a reasonable best-fit straight line — 1 point

<u>Note</u>: Circles on the graph are to indicate points chosen to calculate slope in part (b). They are not necessary to receive credit.

Question 2 (continued)

Distribution of points

(b) 3 points

For correctly using the equation $R = \rho L/A$ to solve for the resistivity — 1 point

$\rho = (R/L)A$

For calculating the slope m from two points that lie on the indicated best-fit line — 1 point

Example (using the two points indicated on the graph)

$$m = \Delta R/\Delta L = \left(340 \times 10^3\ \Omega - 140 \times 10^3\ \Omega\right)/(0.076\text{ m - }0.032\text{ m})$$

$$m = 4.55 \times 10^6\ \Omega/\text{m}$$

Note: The slope point can also be earned for indicating that a linear regression function on a calculator was used (exact answer required): $m = 4.5 \times 10^6\ \Omega/\text{m}$ (to two significant figures).

$\rho = mA = mtw$

$\rho = \left(4.5 \times 10^6\ \Omega/\text{m}\right)\left(1.0 \times 10^{-4}\text{ m}\right)(0.02\text{ m})$

For a correct answer, with supporting work — 1 point

$\rho = 9.0\ \Omega\text{•m}$ $(\pm 0.2\ \Omega\text{•m is acceptable})$

(c) 3 points

For correctly stating the RC circuit time constant equation — 1 point

$\tau = RC$

For the correct value of the equivalent resistance — 1 point

$$\frac{1}{R_P} = \frac{1}{R4} + \frac{1}{R5} = \frac{1}{(370\text{ k}\Omega)} + \frac{1}{(440\text{ k}\Omega)}$$

$R_P = 201\text{ k}\Omega$

For the correct value of the time constant (units not evaluated here) — 1 point

$\tau = R_P C = (201\text{ k}\Omega)(10\ \mu\text{F})$

$\tau = 2.01\text{ s}$

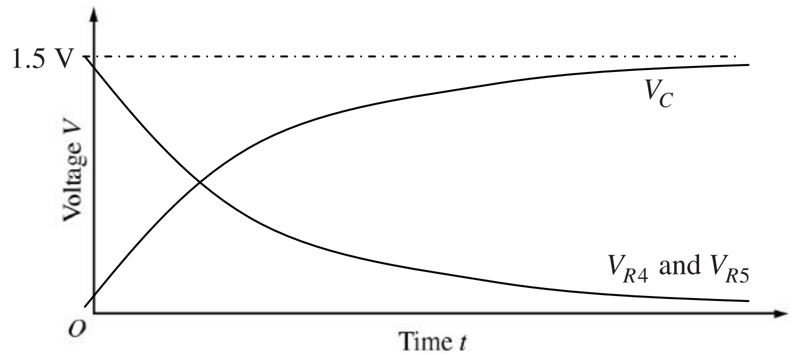
Units 1 point

For correct units for the answers in both parts (b) and (c) — 1 point

Question 2 (continued)

Distribution of points

(d) 4 points



For correctly indicating the battery voltage as an asymptote for the V_C curve (or in the absence of a correct V_C curve, as the maximum of the resistor curves) — 1 point

For a capacitor voltage curve starting at the origin, increasing, concave down, and appropriately labeled — 1 point

For a resistor voltage curve starting at the intersection of the asymptotic voltage with the voltage axis, decreasing and concave up (asymptotic with the time axis), and appropriately labeled — 1 point

For any indication that $V_{R4} = V_{R5}$ — 1 point

Question 3

15 points total | **Distribution of points**

(a) 1 point

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

For a correct answer — 1 point

$\phi_m = B_0 L h_0$

(b) 2 points

For a correct direction arrow — 1 point

For a valid justification using Lenz's Law or the right-hand rule, if the direction is also correct — 1 point

Examples

The flux is decreasing as the area is decreasing, and a current to the right would cause an inward magnetic field that would increase flux.

The force on the falling positive charge carriers is to the right, which causes a conventional current to the right.

(c) 3 points

For a correct relationship between current, voltage, and resistance — 1 point

$I = \dfrac{\mathcal{E}}{R}$

For a correct relationship between the induced emf and the magnetic field — 1 point

$|\mathcal{E}| = \dfrac{d\phi_m}{dt}$

$|\mathcal{E}| = B_0 L \dfrac{dh}{dt}$

$|\mathcal{E}| = B_0 L \upsilon$

For a correct answer# — 1 point

$I = B_0 L \upsilon / R$

Note: If only the correct answer is given, with no accompanying work, only 1 point can be awarded.

Question 3 (continued)

Distribution of points

(d) 4 points

For a correct net force equation showing opposite directions for the gravitational and magnetic forces, F_g and F_M — 1 point

$$\sum F = ma = F_g - F_M = mg - F_M$$

$$a = g - \frac{F_M}{m}$$

For using an appropriate equation to find F_M — 1 point

$$F_M = \int I \left| d\ell \times \mathbf{B} \right| = ILB_0$$

For substituting the current from part (c) — 1 point

$$F_M = \left(\frac{B_0 L \upsilon}{R}\right) LB_0 = \frac{B_0^2 L^2 \upsilon}{R}$$

For expressing acceleration a as $d\upsilon/dt$ — 1 point

$$\frac{d\upsilon}{dt} = g - \frac{B_0^2 L^2 \upsilon}{mR}$$

(e) 2 points

For setting the gravitational force equal to the magnetic force — 1 point

$a = 0$; therefore $F_M = F_g$

For correct substitution of expressions for the forces — 1 point

$$mg = ILB_0 = B_0^2 L^2 \upsilon_T / R$$

$$\upsilon_T = \frac{mgR}{B_0^2 L^2}$$

Note: If the correct expression for υ_T is stated without support, 2 points are awarded.

Question 3 (continued)

Distribution of points

(f) 3 points

For correctly checking "Increases" — 1 point

<u>Note</u>: If an incorrect choice is made for the change in terminal speed, the justification points cannot be earned.

For indicating the inverse relationship between resistance and current — 1 point

For indicating that a smaller current produces a smaller magnetic force on the bar, leading to the conclusion that to achieve a magnetic force equal to the bar's weight, the bar must be moving faster to produce the necessary current in the bar. — 1 point

<u>Note</u>: If the only justification is stating that $\upsilon_T \propto R$ from the equation for υ_T in part (e), only 1 justification point is awarded, because the question specifically asks for the answer in terms of forces on the crossbar.

GO ON TO THE NEXT PAGE.

Scoring Worksheet

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

2012 AP Physics C: Electricity and Magnetism Scoring Worksheet

Section I: Multiple Choice

____________ $\times$ 1.2857 = ____________

Number Correct (out of 35) — Weighted Section I Score (Do not round)

Section II: Free Response

Question 1 __________ (out of 15) $\times$ 1.0000 = __________ (Do not round)

Question 2 __________ (out of 15) $\times$ 1.0000 = __________ (Do not round)

Question 3 __________ (out of 15) $\times$ 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: Electricity and Magnetism

Composite Score Range	AP Score
52-90	5
39-51	4
32-38	3
22-31	2
0-21	1

AP Physics C: Electricity and Magnetism