

Setting a Policy for AP[®] Physics

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The purpose of this guide is to provide college faculty and administrators with research data, participation and performance data of AP[®] Physics students, curricular content, and sample exam questions to facilitate the establishment of appropriate credit and placement policies for AP Physics.

The Advanced Placement Program[®] (AP) provides motivated students with the opportunity to take college-level courses while still in high school. Students demonstrate their mastery of the curriculum by taking AP Exams—35 exams, including three in Physics, are available in 20 subject areas. In 2005, more than 1.2 million students took AP Exams worldwide. Of the 2.1 million AP Exams taken in 2005, more than 81,000 were in Physics (about 47,000 for Physics B, 24,000 for Physics C: Mechanics, and 11,000 for Physics C: Electricity and Magnetism). More than 3,000 colleges and universities, including many international institutions, accept qualifying AP Exam scores for credit, placement, or both.

Throughout its 50-year history, the AP Program has maintained high standards of rigor in its courses and exams. Since its inception, AP has been a respected force in American education due to the critical involvement of college and university faculty members.

Physics Faculty Involvement in AP

College and university faculty members play a vital role in every stage of development and scoring of an AP course and exam, helping to ensure their high quality. Each AP discipline has its own Development Committee—composed of college and university professors and experienced AP teachers—that is responsible for creating the course guidelines and exam questions. College and university faculty members also serve as the Chief Readers, responsible for establishing the exam-scoring guidelines and overseeing the annual AP Reading of the free-response section for their academic discipline.

“Participating in the AP Physics program has been an eye-opening and worthwhile experience. Teaching at a college where many students have succeeded in AP courses in high school has given me an appreciation for the rigor of the AP curriculum. In physics, students with high AP scores usually move easily into the next course in the sequence. I am a better teacher because of my involvement with the AP Program and my conversations and interactions with high school AP teachers and college and university teachers who are on the Development Committee and are Exam Readers.”

—Laurence Cain, AP Physics Development Committee Chair
Davidson College

How to Set an AP Policy

The College Board encourages higher education institutions to base their AP policy decisions on data and research, and recognizes that different institutions and departments will set different policies, based upon factors unique to their institution, student body, and academic discipline. The best way for colleges and universities to determine their AP credit and placement policies is to conduct their own research on the performance of AP and non-AP students at their own institution and in their own department.

Research on AP Physics Student Performance

Research studies show that students who do well on an AP Exam are academically prepared to place out of a corresponding college course and move on to the next higher-level course in the discipline. See Tables 1, 2, and 3 for data from a research study comparing AP and non-AP student performance in second- and third-level college Physics courses.

Table 1: Student Performance in Second-Level Physics Courses AP Physics B Students Versus Non-AP Students

	AP EXAM GRADE	GPA	PERCENT OF STUDENTS SCORING AN A OR B
AP Physics B Students Who Place Out of Intro. Course	AP 5	3.62	98
	AP 4	3.33	85
	AP 3	2.89	64
Students Who Complete Intro. Course	Non-AP	2.67	59

Table 2: Student Performance in Second- and Third-Level Physics Courses AP Physics C: Mechanics Students Versus Non-AP Students

	AP EXAM GRADE	SECOND-LEVEL COURSES		THIRD-LEVEL COURSES	
		GPA	PERCENT OF STUDENTS SCORING AN A OR B	GPA	PERCENT OF STUDENTS SCORING AN A OR B
AP Physics C: Mechanics Students Who Place Out of Intro. Course	AP 5	3.37	87	3.33	88
	AP 4	2.75	69	3.01	74
	AP 3	2.81	65	2.93	73
Students Who Complete Intro. Course	Non-AP	2.62	56	2.69	59

Table 3: Student Performance in Second- and Third-Level Physics Courses

AP Physics C: Electricity and Magnetism Students Versus Non-AP Students

	AP EXAM GRADE	SECOND-LEVEL COURSES		THIRD-LEVEL COURSES	
		GPA	PERCENT OF STUDENTS SCORING AN A OR B	GPA	PERCENT OF STUDENTS SCORING AN A OR B
AP Physics C: E&M Students Who Place Out of Intro. Course	AP 5	3.29	81	3.42	91
	AP 4	3.01	77	2.84	69
	AP 3	2.89	68	*	*
Students Who Complete Intro. Course	Non-AP	2.62	56	2.69	59

* Sample too small to draw conclusions

Taking the AP course and exam stimulates further interest in the subject area and encourages deeper disciplinary knowledge.

Research studies show that students who take the AP Physics Exams are significantly more likely to take further course work in physics and engineering than students who do not take the AP Exam. Higher scores on the AP Exam make this trend even more pronounced, with a greater likelihood of majoring or minoring in the discipline. See Tables 4, 5, and 6 for data from this research study.

Table 4: Additional College Physics Course Work AP Physics B Students Versus Non-AP Students

	AP EXAM GRADE	PERCENT TAKING ADDITIONAL PHYSICS COURSES	AVERAGE NUMBER OF COLLEGE PHYSICS COURSES TAKEN
AP Physics B Students	AP 5	77	2.4
	AP 4	69	2.4
	AP 3	70	1.8
	AP 2	68	1.5
	AP 1	56	1.3
Non-AP Students	Non-AP	47	1.0

Table 5: Additional College Physics Course Work AP Physics C: Mechanics Versus Non-AP Students

	AP EXAM GRADE	PERCENT TAKING ADDITIONAL PHYSICS COURSES	AVERAGE NUMBER OF COLLEGE PHYSICS COURSES TAKEN
AP Physics C: Mechanics Students	AP 5	83	3.6
	AP 4	77	3.0
	AP 3	78	2.8
	AP 2	74	3.1
Non-AP Students	Non-AP	47	1.2

Table 6: Additional College Physics Course Work
AP Physics C: Electricity and Magnetism Students Versus
Non-AP Students

	AP EXAM GRADE	PERCENT TAKING ADDITIONAL PHYSICS COURSES	AVERAGE NUMBER OF COLLEGE PHYSICS COURSES TAKEN
AP Physics C: E&M Students	AP 5	85	5.2
	AP 4	81	3.8
	AP 3	82	3.7
	AP 2	78	3.3
Non-AP Students	Non-AP	47	1.4

PDF copies of these and other research studies on AP student performance can be found at apcentral.collegeboard.com/colleges/research.

In addition to research studies on AP student performance, the College Board conducts college comparability studies to measure the degree to which the AP courses and exams are equivalent in content and difficulty to corresponding college courses. The AP Exam scoring rubric is established so that the lowest composite score that earns an AP grade of 5 is equivalent to the average score earned by college students who received grades of A in a comparable course. The lowest score that earns an AP grade of 4 is equivalent to the average B, and the lowest score that earns an AP grade of 3 is equivalent to the average C.

The research that the College Board conducts is intended to help institutions and academic departments as they establish appropriate AP policies. AP Central® (apcentral.collegeboard.com), the College Board's online home for AP professionals, contains other resources that may assist in this process, including the Course Description, released exam questions, and sample student responses at different levels of ability.

For more information go to:

apcentral.collegeboard.com/physicsb/exam

apcentral.collegeboard.com/physicscmec/exam

apcentral.collegeboard.com/physicscem/exam

AP Physics Students, Courses, and Exams

Participation and Performance Data for AP Physics Students in 2005

Total Number of Schools Offering AP Physics B: 3,840

Total Number of Schools Offering AP Physics C: 3,988

Table 7: AP Physics B Exam Score Distribution, 2005

EXAM GRADE	NUMBER OF EXAMINEES	% AT
Score of 5	6,559	14.0%
Score of 4	8,592	18.3%
Score of 3	12,992	27.7%
Score of 2	7,148	15.2%
Score of 1	11,680	24.9%
	46,971	100.0%

Table 8: AP Physics C: Mechanics Exam Score Distribution, 2005

EXAM GRADE	NUMBER OF EXAMINEES	% AT
Score of 5	5,595	23.8%
Score of 4	5,565	23.7%
Score of 3	4,988	21.2%
Score of 2	4,029	17.1%
Score of 1	3,328	14.2%
	23,505	100.0%

Table 9: AP Physics C: Electricity and Magnetism Exam Score Distribution, 2005

EXAM GRADE	NUMBER OF EXAMINEES	% AT
Score of 5	3,395	30.4%
Score of 4	2,625	23.5%
Score of 3	1,490	13.3%
Score of 2	1,991	17.8%
Score of 1	1,676	15.0%
	11,177	100.0%

“The annual AP Physics Reading brings together more than one hundred college and university professors and experienced AP teachers from throughout the U.S. (and sometimes beyond). Readers reflect the full individual and institutional diversity of physics teaching, yet we are all dedicated to fairly and accurately assessing and reporting each student's exam performance. The Reading provides a wonderful opportunity for establishing professional ties and enduring friendships.”

—William Ingham
AP Physics Development Committee Chief Reader
James Madison University

AP Credit Policy Info on the Web

Information about AP credit and placement policies at more than 1,000 colleges and universities is available on the College Board's Web site at

www.collegeboard.com/ap/creditpolicy.

Figure 1: AP Physics B Examinees by Gender, 2005

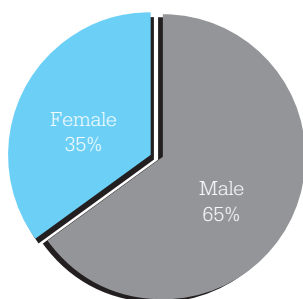


Figure 2: AP Physics C Examinees by Gender, 2005

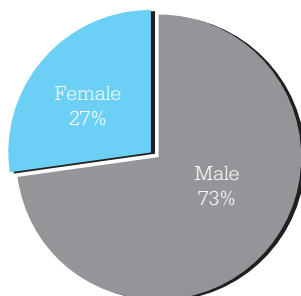


Figure 3: AP Physics B Examinees by Race and Ethnicity, 2005

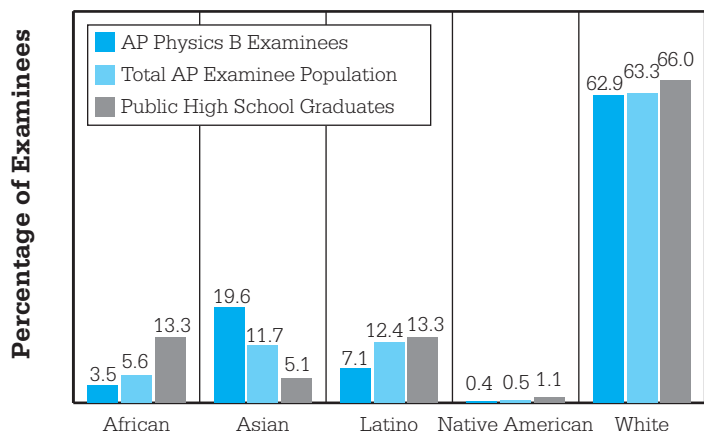
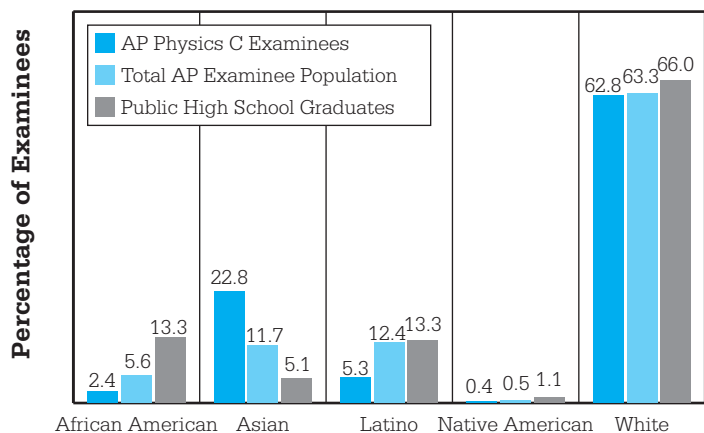


Figure 4: AP Physics C Examinees by Race and Ethnicity, 2005



“Laboratory experience must be part of the education of AP Physics students and should be included in all AP Physics courses, just as it is in introductory college physics courses. AP students should be able to:

- Design experiments;
- Observe and measure real phenomena;
- Organize, display, and critically analyze data;
- Analyze sources of error and determine uncertainties in measurement;
- Draw inferences from observations and data; and
- Communicate results, including suggested ways to improve experiments and proposed questions for further study.”

—AP Physics Course Description

The AP Physics Courses

All AP Physics courses are designed to provide students with a learning experience equivalent to that of a college course in physics. All AP Physics courses include a college-level laboratory component.

The Physics B course includes topics in both classical and modern physics. Knowledge of algebra and trigonometry is required; some theoretical developments may also use basic concepts of calculus. Five general areas of physics are covered in the Physics B course: Newtonian mechanics; fluid mechanics and thermal physics; electricity and magnetism; waves and optics; and atomic and nuclear physics.

There are two AP Physics C courses: one focusing on mechanics and the other on electricity and magnetism. Students are permitted to take either or both AP Physics C Exams. Introductory differential and integral calculus is used throughout both courses and on the exams.

The College Board recently began a major long-term initiative, in conjunction with the National Science Foundation, aimed at improving the quality of learning and teaching in AP science courses. This was undertaken in response to a 2002 report on advanced studies in mathematics and science by the National Research Council that recommended specific changes in advanced high school studies in the sciences. A special task force is currently evaluating the AP Physics courses and will draft recommendations to be presented to the Development Committee, which develops the course guidelines and designs the AP Exams.

The Development Committee has created a topic outline that covers the main content areas that should be taught in each Physics course, along with the relative weight to be assigned to each topic:

Content Area	Percentage Goals for Exams	
	Physics B	Physics C
I. Newtonian Mechanics	35%	50%
A. Kinematics (including vectors, vector algebra, components of vectors, coordinate systems, displacement, velocity, and acceleration)	7%	9%
1. Motion in one dimension	✓	✓
2. Motion in two dimensions, including projectile motion	✓	✓

Content Area	Percentage Goals for Exams	
	Physics B	Physics C
B. Newton's laws of motion	9%	10%
1. Static equilibrium (first law)	✓	✓
2. Dynamics of a single particle (second law)	✓	✓
3. Systems of two or more objects (third law)	✓	✓
C. Work, energy, power	5%	7%
1. Work and work-energy theorem	✓	✓
2. Forces and potential energy	✓	✓
3. Conservation of energy	✓	✓
4. Power	✓	✓
D. Systems of particles, linear momentum	4%	6%
1. Center of mass		✓
2. Impulse and momentum	✓	✓
3. Conservation of linear momentum, collisions	✓	✓
E. Circular motion and rotation	4%	9%
1. Uniform circular motion	✓	✓
2. Torque and rotational statics	✓	✓
3. Rotational kinematics and dynamics		✓
4. Angular momentum and its conservation		✓
F. Oscillations and gravitation	6%	9%
1. Simple harmonic motion (dynamics and energy relationships)	✓	✓
2. Mass on a spring	✓	✓
3. Pendulum and other oscillations	✓	✓
4. Newton's law of gravity	✓	✓
5. Orbits of planets and satellites		✓
a. Circular	✓	✓
b. General		✓
II. Fluid Mechanics and Thermal Physics	15%	
A. Fluid Mechanics	6%	
1. Hydrostatic pressure	✓	
2. Buoyancy	✓	
3. Fluid flow continuity	✓	
4. Bernoulli's equation	✓	
B. Temperature and heat	2%	
1. Mechanical equivalent of heat	✓	
2. Heat transfer and thermal expansion	✓	
C. Kinetic theory and thermodynamics	7%	
1. Ideal gases		
a. Kinetic model	✓	
b. Ideal gas law	✓	
2. Laws of thermodynamics		
a. First law (including processes on pV diagrams)	✓	
b. Second law (including heat engines)	✓	
III. Electricity and Magnetism	25%	50%
A. Electrostatics	5%	15%
1. Charge and Coulomb's law	✓	✓
2. Electric field and electric potential (including point charges)	✓	✓
3. Gauss's law		✓
4. Fields and potentials of other charge distributions		✓
B. Conductors, capacitors, dielectrics	4%	7%
1. Electrostatics with conductors	✓	✓
2. Capacitors		
a. Capacitance	✓	✓
b. Parallel plate	✓	✓
c. Spherical and cylindrical		✓
3. Dielectrics		✓
C. Electric circuits	7%	10%
1. Current, resistance, power	✓	✓
2. Steady-state direct current circuits with batteries and resistors only	✓	✓

Content Area	Percentage Goals for Exams	
	Physics B	Physics C
3. Capacitors in circuits		
a. Steady state	✓	✓
b. Transients in RC circuits		✓
D. Magnetic Fields	4%	10%
1. Forces on moving charges in magnetic fields	✓	✓
2. Forces on current-carrying wires in magnetic fields	✓	✓
3. Fields of long current-carrying wires	✓	✓
4. Biot-Savart law and Ampere's law		✓
E. Electromagnetism	5%	8%
1. Electromagnetic induction (including Faraday's law and Lenz's law)	✓	✓
2. Inductance (including LR and LC circuits)		✓
3. Maxwell's equations		
IV. Waves and Optics	15%	
A. Wave motion (including sound)	5%	
1. Traveling waves	✓	
2. Wave propagation	✓	
3. Standing waves	✓	
4. Superposition	✓	
B. Physical optics	5%	
1. Interference and diffraction	✓	
2. Dispersion of light and the electromagnetic spectrum	✓	
C. Geometric optics	5%	
1. Reflection and refraction	✓	
2. Mirrors	✓	
3. Lenses	✓	
V. Atomic and Nuclear Physics	10%	
A. Atomic physics and quantum effects	7%	
1. Photons, the photoelectric effect, Compton scattering, x-rays	✓	
2. Atomic energy levels	✓	
3. Wave-particle duality	✓	
B. Nuclear physics	3%	
1. Nuclear reactions (including conservation of mass number and charge)	✓	
2. Mass-energy equivalence	✓	

Beginning in fall 2006, AP Physics teachers and principals of schools where AP Physics is taught must certify that their 2007-08 courses follow all the requirements stipulated by the Development Committee, including using a college-level textbook and providing the class time and equipment to complete the necessary laboratories, in order to ensure that the AP course reflects college-level standards. By completing this AP Course Audit, high schools will receive individual licenses to label their physics courses "AP." In fall 2007, colleges and universities will receive a list of all high schools authorized to use the "AP" designation for their physics courses.

The AP Physics Exams

All three AP Physics Exams include two equally weighted sections: multiple choice and free response. The AP Physics B Exam is three hours long; each AP Physics C Exam is 1 hour and 30 minutes long. Students may choose to take either one or both AP Physics C Exams.

On all AP Physics Exams the multiple-choice section emphasizes the breadth of the students' knowledge and understanding of the basic principles of physics; the free-response section emphasizes the application of these principles in greater depth in solving more extended problems. In general, questions may ask students to:

- determine directions of vectors or paths of particles
- draw or interpret diagrams
- interpret or express physical relationships in graphical form
- account for observed phenomena
- interpret experimental data, including their limitations and uncertainties
- construct and use conceptual models and explain their limitations
- explain steps taken to arrive at a result or to predict future physical behavior
- manipulate equations that describe physical relationships
- obtain reasonable estimates
- solve problems that require the determination of physical quantities in either numerical or symbolic form and that may require the application of single or multiple physical concepts

Laboratory-related questions may ask students to:

- design experiments, including identifying equipment needed and describing how it is to be used, drawing diagrams or providing descriptions of experimental setups, or describing procedures to be used, including controls and measurements to be taken
- analyze data, including displaying data in graphical or tabular form, fitting lines and curves to data points in graphs, performing calculations with data, or making extrapolations and interpolations from data
- analyze errors, including identifying sources of errors and how they propagate, estimating magnitude and direction of errors, determining significant digits, or identifying ways to reduce errors
- communicate results, including drawing inferences and conclusions from experimental data, suggesting ways to improve experiments, or proposing questions for further study

The AP Physics B Exam free-response section usually includes six or seven questions; each AP Physics C Exam free-response section has traditionally had three questions. The free-response questions may involve topics from two or more major categories in the topic outline. Each AP Physics Exam includes one or more questions or parts of questions posed in a laboratory or experimental setting.

The use of calculators is permitted on the free-response section of all the AP Physics Exams, but not on the multiple-choice section. Any numeric calculations using equations required on the multiple-choice section are kept simple. Tables containing commonly used physics equations are provided with each exam for students to use when taking the free-response section. These equation tables may not be used by students during the multiple-choice section. The

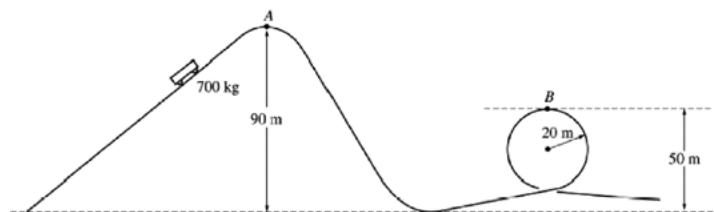
purpose of minimizing numerical calculations in both sections of the exams and providing equations with the free-response sections is to place greater emphasis on the understanding and application of fundamental physical principles and concepts.

“As any teacher knows, it can be difficult to write a question with no ambiguities. Now imagine writing a test that over 40,000 students will take. You need to make sure there is nothing in the language that could confuse students. For something like lab questions, you need to be able to ask a question that will get at what you want to know, even if the student has seen a quite different presentation. By bringing together a committee of dedicated teachers from different levels, we can carefully work to meet these goals.”

—Gay Stewart, AP Physics Development Committee former Chair
University of Arkansas, Fayetteville

AP Physics free-response questions from recent exam years are listed below.

Question 1 (Physics B)



A roller coaster ride at an amusement park lifts a car of mass 700 kg to point A at a height of 90 m above the lowest point on the track, as shown above. The car starts from rest at point A, rolls with negligible friction down the incline and follows the track around a loop of radius 20 m. Point B, the highest point on the loop, is at a height of 50 m above the lowest point on the track.

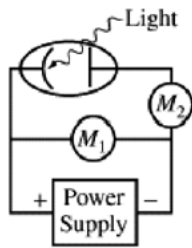
- Indicate on the figure the point P at which the maximum speed of the car is attained.
 - Calculate the value v_{\max} of this maximum speed.
- Calculate the speed v_B of the car at point B.
 - On the figure of the car below, draw and label vectors to represent the forces acting on the car when it is upside down at point B.



- Calculate the magnitude of all the forces identified in (c) i.

- (d) Now suppose that friction is not negligible. How could the loop be modified to maintain the same speed at the top of the loop as found in (b)? Justify your answer.

Question 2 (Physics B)



A student performs a photoelectric effect experiment in which light of various frequencies is incident on a photosensitive metal plate. This plate, a second metal plate, and a power supply are connected in a circuit, which also contains two meters, M_1 and M_2 , as shown above.

The student shines light of a specific wavelength λ onto the plate. The voltage on the power supply is then adjusted until there is no more current in the circuit, and this voltage is recorded as the stopping potential V_s .

The student then repeats the experiment several more times with different wavelengths of light. The data, along with other values calculated from it, are recorded in the table below.

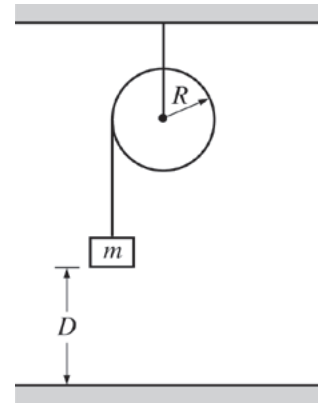
λ (m)	4.00×10^{-7}	4.25×10^{-7}	4.50×10^{-7}	4.75×10^{-7}
V_s (volts)	0.65	0.45	0.30	0.15
f (Hz)	7.50×10^{14}	7.06×10^{14}	6.67×10^{14}	6.32×10^{14}
K_{\max} (eV)	0.65	0.45	0.30	0.15

- (a) Indicate which meter is used as an ammeter and which meter is used as a voltmeter by checking the appropriate spaces below.

	M_1	M_2
Ammeter	_____	_____
Voltmeter	_____	_____

- (b) Use the data above to plot a graph of K_{\max} versus f on the axes below, and sketch a best-fit line through the data. [Graph with labeled axes provided in exam book for student.]
- (c) Use the best-fit line you sketched in part (b) to calculate an experimental value for Planck's constant.
- (d) If the student had used a different metal with a larger work function, how would the graph you sketched in part (b) be different? Explain your reasoning.

Question 3 (Physics C: Mechanics)



A solid disk of unknown mass and known radius R is used as a pulley in a lab experiment, as shown above.

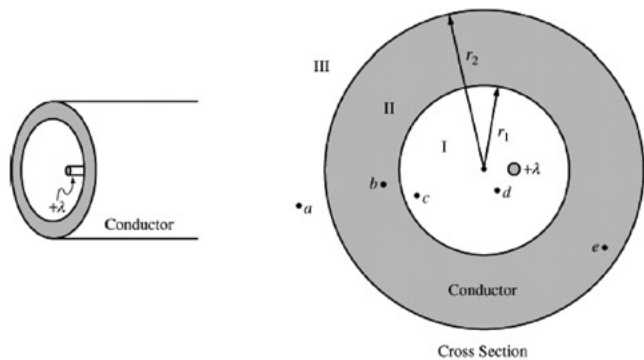
A small block of mass m is attached to a string, the other end of which is attached to the pulley and wrapped around it several times. The block of mass m is released from rest and takes a time t to fall the distance D to the floor.

- (a) Calculate the linear acceleration a of the falling block in terms of the given quantities.
- (b) The time t is measured for various heights D and the data are recorded in the following table.

D (m)	t (s)
0.5	0.68
1.0	1.02
1.5	1.19
2.0	1.38

- i. What quantities should be graphed in order to best determine the acceleration of the block? Explain your reasoning.
- ii. On the grid below, plot the quantities determined in (b)i., label the axes, and draw the best-fit line to the data. [Grid without labeled axes provided in exam book for student.]
- iii. Use your graph to calculate the magnitude of the acceleration.
- (c) Calculate the rotational inertia of the pulley in terms of m , R , a , and fundamental constants.
- (d) The value of acceleration found in (b)iii, along with numerical values for the given quantities and your answer to (c), can be used to determine the rotational inertia of the pulley. The pulley is removed from its support and its rotational inertia is found to be greater than this value. Give one explanation for this discrepancy.

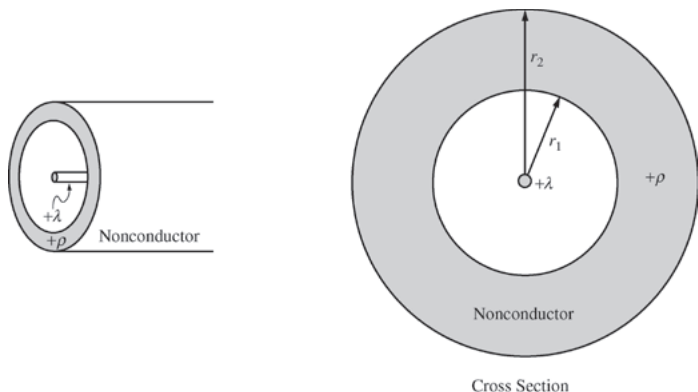
Question 4 (Physics C: Electricity and Magnetism)



The figure above left shows a hollow, infinite, cylindrical, uncharged conducting shell of inner radius r_1 and outer radius r_2 . An infinite line charge of linear charge density $+\lambda$ is parallel to its axis but off center. An enlarged cross section of the cylindrical shell is shown above right.

- (a) On the cross section above right,
- sketch the electric field lines, if any, in each of regions I, II, and III and
 - use $+$ and $-$ signs to indicate any charge induced on the conductor.
- (b) In the spaces below, rank the electric potentials at points a , b , c , d , and e from highest to lowest (1 = highest potential). If two points are at the same potential, give them the same number.

___ V_a ___ V_b ___ V_c ___ V_d ___ V_e



- (c) The shell is replaced by another cylindrical shell that has the same dimensions but is nonconducting and carries a uniform volume charge density $+\rho$. The infinite line charge, still of charge density $+\lambda$, is located at the center of the shell as shown above. Using Gauss's law, calculate the magnitude of the electric field as a function of the distance r from the center of the shell for each of the following regions. Express your answers in terms of the given quantities and fundamental constants.

- $r < r_1$
- $r_1 \leq r \leq r_2$
- $r > r_2$

How to Get Involved

There are many ways college and university faculty members can help maintain the high standards of the AP Program:

- Participate in a college comparability study
- Be an AP Reader
- Contribute multiple-choice test items for the AP Exam
- Become an AP Faculty Consultant

For more information, please go to: apcentral.collegeboard.com/highered/getinvolved

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The College Board: Connecting Students to College Success

The College Board is a not-for-profit membership association whose mission is to connect students to college success and opportunity. Founded in 1900, the association is composed of more than 5,000 schools, colleges, universities, and other educational organizations. Each year, the College Board serves seven million students and their parents, 23,000 high schools, and 3,500 colleges through major programs and services in college admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT®, the PSAT/NMSQT®, and the Advanced Placement Program® (AP®). The College Board is committed to the principles of excellence and equity, and that commitment is embodied in all of its programs, services, activities, and concerns. For further information, visit www.collegeboard.com.