AP Physics C: Electricity and Magnetism
2001 Free-Response Questions

These materials were produced by Educational Testing Service (ETS), which develops and administers the examinations of the Advanced Placement Program for the College Board. The College Board and Educational Testing Service (ETS) are dedicated to the principle of equal opportunity, and their programs, services, and employment policies are guided by that principle.

The College Board is a national nonprofit membership association dedicated to preparing, inspiring, and connecting students to college and opportunity. Founded in 1900, the association is composed of more than 3,900 schools, colleges, universities, and other educational organizations. Each year, the College Board serves over three million students and their parents, 22,000 high schools, and 3,500 colleges, through major programs and services in college admission, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT®, the PSAT/NMSQT™, the Advanced Placement Program® (AP®), and Pacesetter®. The College Board is committed to the principles of equity and excellence, and that commitment is embodied in all of its programs, services, activities, and concerns.

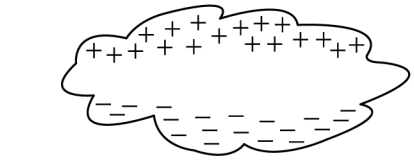
2001 AP® PHYSICS C: ELECTRICITY AND MAGNETISM
FREE-RESPONSE QUESTIONS

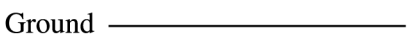
PHYSICS C

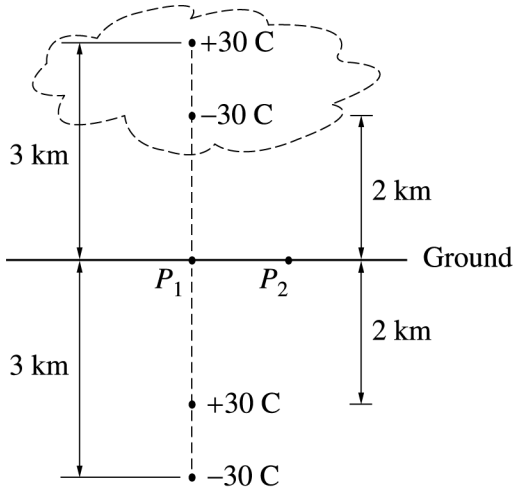
Section II, ELECTRICITY AND MAGNETISM
Time—45 minutes

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 the pink booklet in the spaces provided after each part, NOT in this green insert.







Note: Figures not drawn to scale.

E&M 1.

A thundercloud has the charge distribution illustrated above left. Treat this distribution as two point charges, a negative charge of −30 C at a height of 2 km above ground and a positive charge of +30 C at a height of 3 km. The presence of these charges induces charges on the ground. Assuming the ground is a conductor, it can be shown that the induced charges can be treated as a charge of +30 C at a depth of 2 km below ground and a charge of −30 C at a depth of 3 km, as shown above right. Consider point P_1, which is just above the ground directly below the thundercloud, and point P_2, which is 1 km horizontally away from P_1.

(a) Determine the direction and magnitude of the electric field at point P_1.

(b) i. On the diagram above, clearly indicate the direction of the electric field at point P_2.

ii. How does the magnitude of the field at this point compare with the magnitude at point P_1?

___ Greater ___ Equal ___ Less

Justify your answer

(c) Letting the zero of potential be at infinity, determine the potential at these points.

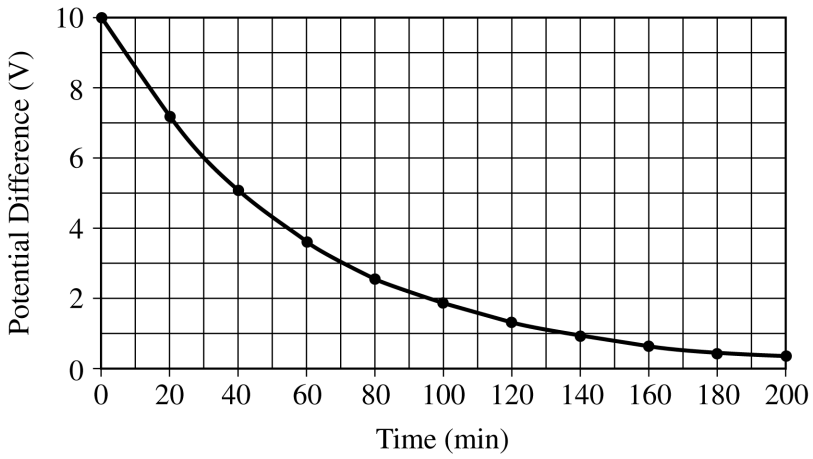
i. Point P_1

ii. Point P_2

(d) Determine the electric potential at an altitude of 1 km directly above point P_1.

(e) Determine the total electric potential energy of this arrangement of charges.

GO ON TO THE NEXT PAGE.



E & M 2.

You have been hired to determine the internal resistance of 8.0 μF capacitors for an electronic component manufacturer. (Ideal capacitors have an infinite internal resistance—that is, the material between their plates is a perfect insulator. In practice, however, the material has a very small, but nonzero, conductivity.) You cannot simply connect the capacitors to an ohmmeter, because their resistance is too large for an ohmmeter to measure. Therefore you charge the capacitor to a potential difference of 10 V with a battery, disconnect it from the battery and measure the potential difference across the capacitor every 20 minutes with an ideal voltmeter, obtaining the graph shown above.

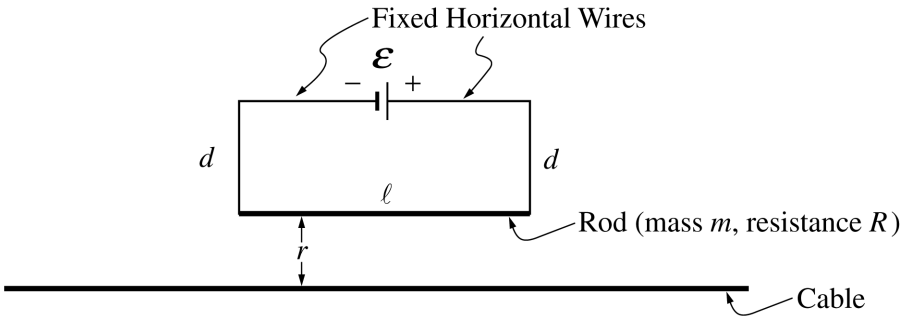
(a) Determine the internal resistance of the capacitor.

The capacitor can be approximated as a parallel-plate capacitor separated by a 0.10 mm thick dielectric with $\kappa = 5.6$.

(b) Determine the approximate surface area of one of the capacitor "plates."

(c) Determine the resistivity of the dielectric.

(d) Determine the magnitude of the charge leaving the positive plate of the capacitor in the first 100 min.



E&M 3.

The circuit shown above consists of a battery of emf $\mathcal{E}$ in series with a rod of length ℓ, mass m, and resistance R. The rod is suspended by vertical connecting wires of length d, and the horizontal wires that connect to the battery are fixed. All these wires have negligible mass and resistance. The rod is a distance r above a conducting cable. The cable is very long and is located directly below and parallel to the rod. Earth's gravitational pull is toward the bottom of the page. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) What is the magnitude and direction of the current I in the rod?

(b) In which direction must there be a current in the cable to exert an upward force on the rod? Justify your answer.

(c) With the proper current in the cable, the rod can be lifted up such that there is no tension in the connecting wires. Determine the minimum current I_c in the cable that satisfies this situation.

(d) Determine the magnitude of the magnetic flux through the circuit due to the minimum current I_c determined in part (c).

END OF SECTION II, ELECTRICITY AND MAGNETISM