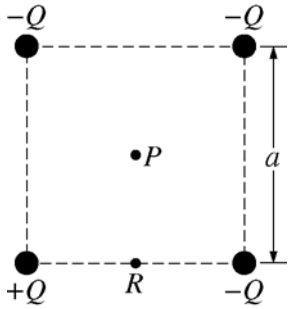
PHYSICS C: ELECTRICITY AND MAGNETISM

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



E&M 1.

The square of side a above contains a positive point charge $+Q$ fixed at the lower left corner and negative point charges $-Q$ fixed at the other three corners of the square. Point P is located at the center of the square.

(a) On the diagram, indicate with an arrow the direction of the net electric field at point P.

(b) Derive expressions for each of the following in terms of the given quantities and fundamental constants.

i. The magnitude of the electric field at point P

ii. The electric potential at point P

(c) A positive charge is placed at point P. It is then moved from point P to point R, which is at the midpoint of the bottom side of the square. As the charge is moved, is the work done on it by the electric field positive, negative, or zero?

____ Positive ____ Negative ____ Zero

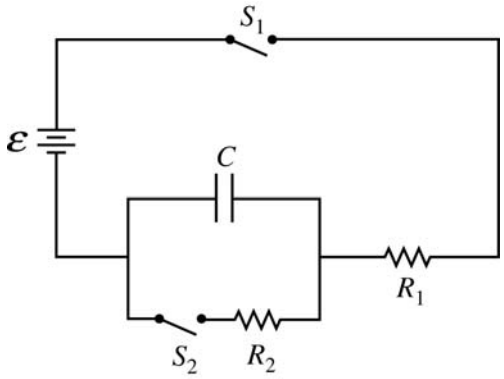
Explain your reasoning.

(d)

i. Describe one way to replace a single charge in this configuration that would make the electric field at the center of the square equal to zero. Justify your answer.

ii. Describe one way to replace a single charge in this configuration such that the electric potential at the center of the square is zero but the electric field is not zero. Justify your answer.

GO ON TO THE NEXT PAGE.



E&M 2.

The circuit above contains a capacitor of capacitance C, a power supply of emf $\mathcal{E}$, two resistors of resistances R_1 and R_2, and two switches, S_1 and S_2. Initially, the capacitor is uncharged and both switches are open. Switch S_1 then gets closed at time $t = 0$.

(a) Write a differential equation that can be solved to obtain the charge on the capacitor as a function of time t.

(b) Solve the differential equation in part (a) to determine the charge on the capacitor as a function of time t.

Numerical values for the components are given as follows:

$\mathcal{E} = 12$ V
$C = 0.060$ F
$R_1 = R_2 = 4700\ \Omega$

(c) Determine the time at which the capacitor has a voltage 4.0 V across it.

After switch S_1 has been closed for a long time, switch S_2 gets closed at a new time $t = 0$.

(d) On the axes below, sketch graphs of the current I_1 in R_1 versus time and of the current I_2 in R_2 versus time, beginning when switch S_2 is closed at new time $t = 0$. Clearly label which graph is I_1 and which is I_2.

Question 1 (continued)

Distribution of points

(d)

(i) 2 points

For replacing the top right negative charge with a positive charge OR replacing the bottom left positive charge with a negative charge — 1 point

For an appropriate justification — 1 point

Example:

The vector fields/forces all cancel from oppositely located same charge pairs.

Note: Any obviously incorrect statement resulted in a 1 point deduction.
Examples: "The charges cancelled," or "The field is a scalar," or "The voltage is a vector."

(ii) 3 points

For replacing the top left negative charge with a positive charge OR replacing the bottom right negative charge with a positive charge — 1 point

For an appropriate justification for zero electric potential — 1 point

Example:

The scalar potentials all cancel from equidistant located opposite charge pairs.

For indicating the direction of the resultant nonzero field using words or diagram — 1 point

Note: Any obviously incorrect statement resulted in a 1 point deduction.
Examples: "The charges cancelled," or "The field is a scalar," or "The voltage is a vector."