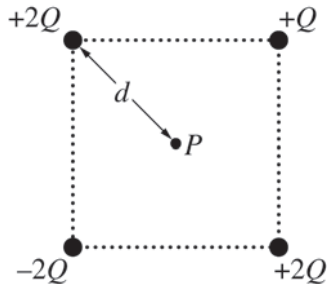
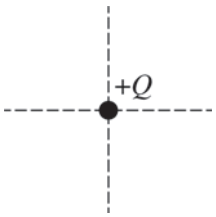


4. (10 points, suggested time 20 minutes)

The figure above represents four objects, with charges as shown, that are held in place at the corners of a square. Point P is at the center of the square, a distance d from each of the objects. Express all algebraic answers to the following in terms of Q, d, and physical constants.

(a) On the dot below, draw an arrow that represents the direction of the net electric force exerted on the object with charge $+Q$ by the other three objects.

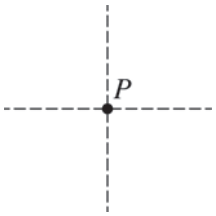


(b)

i. Calculate the magnitude of the electric field at point P due to all four objects. On the dot below, draw an arrow to indicate the direction of the net field at point P.

Draw Arrow

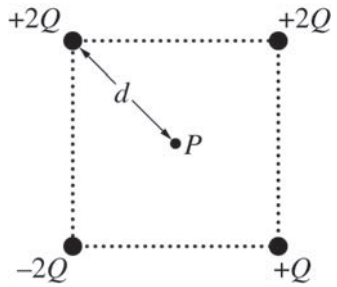
Calculate Electric Field



ii. Calculate the electric potential at point P due to all four objects.

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

(c) In a coherent, paragraph-length response, briefly describe the meaning of electric potential energy and explain qualitatively how electric potential energy can be related to work. Also explain qualitatively how the electric potential energy of the four-object system would change if the $+Q$ and $+2Q$ objects on the right side of the square now switch positions as shown in the figure below. Support your explanation using appropriate physics principles.



STOP

END OF EXAM

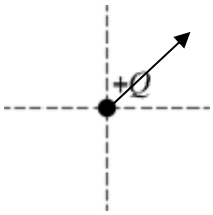
© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

AP® PHYSICS 2
2017 SCORING GUIDELINES

Question 4

10 points total | **Distribution of points**

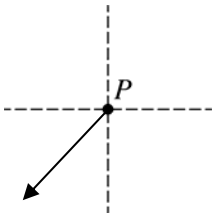
(a) 1 point



For an arrow pointing outward from the object, along a diagonal of the square and away from the object with charge $-2Q$, with no other arrows — 1 point

(b)

i. 3 points



For correctly determining magnitudes of the field from individual objects — 1 point
The fields from the $+2Q$ objects cancel. This can be implicit or explicit in the calculations.

For the $-2Q$ object, $E = 2kQ/d^2$

For the $+Q$ object, $E = kQ/d^2$

For correctly adding the individual fields — 1 point
$E = 3kQ/d^2$

For showing the correct direction on the diagram, along a diagonal of the square and toward the object with charge $-2Q$ — 1 point

ii. 1 point

For showing a correct scalar potential summation — 1 point
A final answer is not required; however, no credit is given if an incorrect final answer is included.

$V = (k/d)(+2Q + Q + 2Q - 2Q) = 3kQ/d$

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.

Question 4 (continued)

Distribution of points

(c) 5 points

For indicating that electric potential energy is the energy stored in a configuration of charged objects — 1 point

For indicating that the change in potential energy is equal to the work done by an external force to create a particular configuration — 1 point

For indicating that moving the object with $+2Q$ charge results in an increase in energy and indicating that moving the object with $+Q$ charge results in a decrease in energy (i.e., for showing understanding that moving charges of the same sign closer together increases the energy and/or moving charges of opposite sign closer together decreases the energy, with some support such as $U = kqQ/r$ or a description of doing work against forces) — 1 point

For indicating that the net result is an increase in the energy with some explanation — 1 point

For a logical, relevant, and internally consistent response that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response — 1 point

© 2017 The College Board.
Visit the College Board on the Web: www.collegeboard.org.