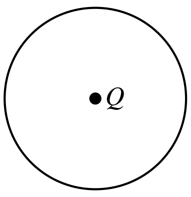
Student #: ____________________________ Student Name: ___________________________________

AP PHYSICS C: ELECTROSTATICS

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 place the letter of your choice in the corresponding box on the student answer sheet.

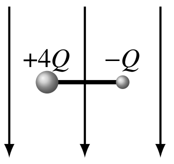
1. A positive charge is placed on a spherical conducting hollow shell of radius R. Which of the following statements is true?
   (A) The charge is distributed evenly on the inside surface of the sphere.
   (B) The charge is distributed evenly on the outside surface of the sphere.
   (C) The charge is concentrated at the center of the sphere.
   (D) The inside surface of the sphere is negatively charged.
   (E) The charge is concentrated at the poles on the surface of the sphere.

Questions 2–3: A positive charge Q is placed at the center of a hollow conducting sphere.



2. The charge on the inside surface of the hollow sphere is
   (A) $-Q$
   (B) $+Q$
   (C) $-2Q$
   (D) $+2Q$
   (E) zero

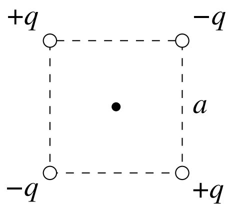
3. A grounding wire is connected to the sphere, and then removed. The charge on the sphere is now
   (A) $-Q$
   (B) $+Q$
   (C) $-2Q$
   (D) $+2Q$
   (E) zero



4. Two charges, $+4Q$ and $-Q$, are connected by an insulated rod and rest in a uniform electric field $\vec{E}$ as shown. Ignore the effects of gravity on the charges and rod. The rod and charges will experience
   (A) a clockwise rotation and a downward acceleration
   (B) a counterclockwise rotation and a downward acceleration
   (C) a clockwise rotation and an upward acceleration
   (D) a counterclockwise rotation and an upward acceleration
   (E) no rotation, but a downward acceleration

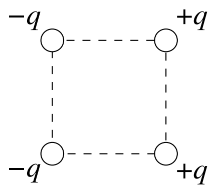
5. An electron and a proton are separated by 1.50×10^{-10} m. If they are released, which one will accelerate at a greater rate, and what is the magnitude of that acceleration?
   (A) The electron; $1.12 \times 10^{22}\ \mathrm{m/s^2}$
   (B) The proton; $1.12 \times 10^{22}\ \mathrm{m/s^2}$
   (C) The electron; $6.13 \times 10^{18}\ \mathrm{m/s^2}$
   (D) The proton; $6.13 \times 10^{18}\ \mathrm{m/s^2}$
   (E) They both accelerate at the same rate; $1.02 \times 10^{-8}\ \mathrm{m/s^2}$

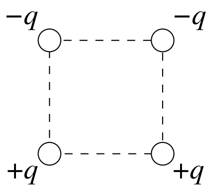
6. Four charges are arranged at the corners of a square of side a as shown. Which of the following is true of the electric field and the electric potential at the center of the square?

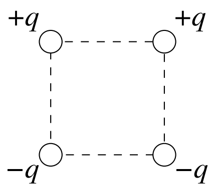


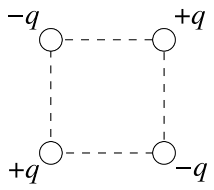
	Electric Field	Electric Potential
(A)	zero	zero
(B)	$\frac{kQ}{a\sqrt{2}}$	zero
(C)	$\frac{kQ^2}{2a^2}$	$\frac{kQ}{2a}$
(D)	zero	$\frac{kQ}{\sqrt{2}a}$
(E)	$\frac{kQ^2}{2a}$	$\frac{kQ}{a\sqrt{2}}$

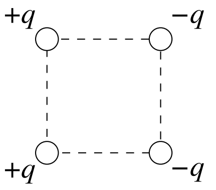
7. Which of the following diagrams best represents how you might rearrange the charges so that the electric field at the center would point directly toward the top of the page?

(A) 

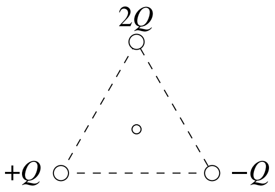
(B) 

(C) 

(D) 

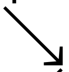
(E) 

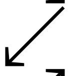
8. Three charges, $+Q$, $-Q$, and $+2Q$, are arranged in an equilateral triangle as shown. Which of the arrows below best represents the direction of the electric field at the center of the triangle?

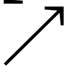


(A) 

(B) 

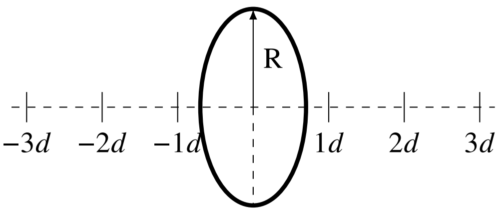
(C) 

(D) 

(E) 

9. Electric potential
   (A) is a vector quantity that depends on the direction of the electric field
   (B) is a scalar quantity that depends on the magnitude and sign of charges in the vicinity
   (C) is a scalar quantity that depends on the square of the distance from the charges in the vicinity
   (D) is a vector quantity that depends on the sign of the charges in the vicinity
   (E) is a vector quantity that must point from high to low potential

10. A positively charged ring of radius R is made of conducting material and has a charge Q distributed uniformly around it. The center of the ring is located at point 0 on the x-axis. The potential V at a distance $3d$ from point 0 on the x-axis is



   (A) $V = \dfrac{kQ}{9d^2}$
   (B) $V = \dfrac{kQ}{3d^2}$
   (C) $V = \dfrac{kQ}{R^2 + 9d^2}$
   (D) $V = \sqrt{\dfrac{kQ}{R^2 + 9d^2}}$
   (E) $V = \dfrac{kQ}{\sqrt{R^2 + 9d^2}}$

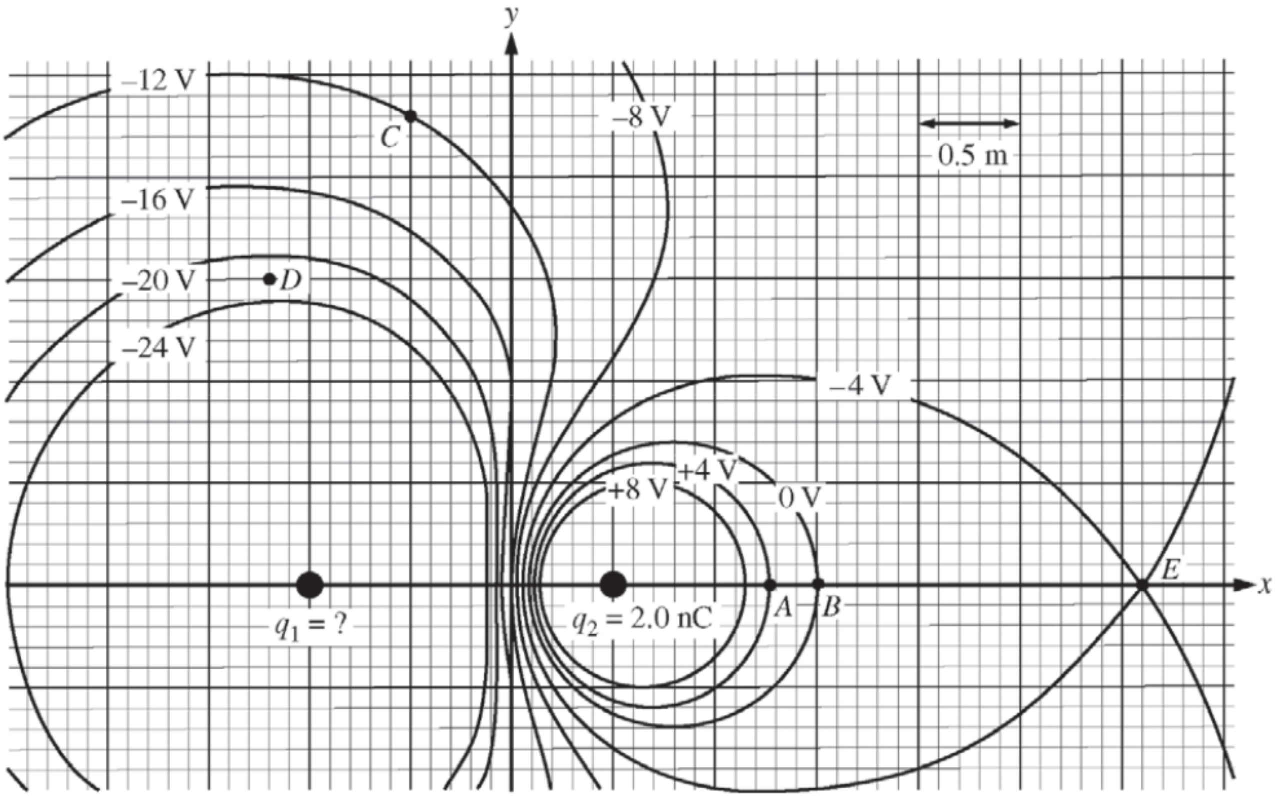
11. Which of the following statements is true of electric field and equipotential lines?
   (A) The electric field vector always points in the same direction as the equipotential lines.
   (B) The electric field always points in the opposite direction of the equipotential lines.
   (C) The electric field always points perpendicular to the equipotential lines.
   (D) The electric field is always equal to the equipotential lines.
   (E) Equipotential lines always form a circle around electric field lines.

12. The potential V as a function of distance r for a particular charge distribution is given by the equation $V = ar^{-1}$. The electric field as a function of distance r from the charge distribution is
   (A) $\frac{1}{3}ar^{-3}$
   (B) $2ar^{-1}$
   (C) ar^{-2}
   (D) $-a(\ln r)$
   (E) $-ar^{-2}$

AP PHYSICS C: ELECTROSTATICS & CAPACITORS
SECTION II
3 Questions

Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.

1. In the Bohr model of the hydrogen atom, the electron moves in a circular orbit of radius r around the proton.
   (a) Find an expression for the kinetic energy of the electron as a function of r. Show that at any distance r the kinetic energy is half the potential energy.
   (b) Evaluate kinetic energy K, potential energy U and the total energy $W = K + U$ in electron volts for $r = 0.529 \times 10^{-10}$ m, the radius of the electron's orbit in hydrogen. (The energy $|W|$ that must be supplied to the hydrogen atom to remove the electron is called the ionization energy.)



2. Two point charges, q_1 and q_2, are fixed in place on the x-axis at positions $x_1 = -1.00$ m and $x_1 = +0.50$ m, respectively. Charge q_2 has a value of 2.0 nC. Values of electric potential are illustrated by the given equipotentials in the diagram shown above, which is drawn to scale.

   (a) Calculate the value of q_1.

   (b) At point C on the diagram, draw a vector representing the direction of the electric field at that point.

   (c) Calculate the approximate magnitude of the electric field strength at point D on the diagram.

   (d) The equipotential labeled 0 V is the cross section of a nearly spherical surface. Calculate the electric flux for this surface.

   (e) A proton is placed at point A and then released from rest.

      i. Calculate the work done by the electric field on the proton as it moves from point A to point E.

      ii. Calculate the speed of the proton when it reaches point E.

   (f) An electron is released from rest at point B. Which of the following indicates the direction of the initial acceleration, if any, of the electron? Justify your answer.

   ____ Up ____ Down ____ Left ____ Right ____ Into the page ____ Out of the page

   ____ The direction is undefined since the acceleration is zero.

3. A spherically symmetric charge distribution has net positive charge Q_0 distributed within a radius of R. Its electric potential V as a function of the distance r from the center of the sphere is given by the following

$$V(r) = \frac{Q_0}{4\pi\epsilon_0 R}\left[-2 + 3\left(\frac{r}{R}\right)^2\right] \text{ for } r < R$$
$$V(r) = \frac{Q_0}{4\pi\epsilon_0 r} \text{ for } r > R$$

Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) For the following regions, indicate the direction of the electric field $E(r)$ and derive an expression for its magnitude.

i. $r < R$

_____ Radially inward

_____ Radially outward

ii. $r > R$

_____ Radially inward

_____ Radially outward

(b) For the following regions, derive an expression for the enclosed charge that generates the electric field in that region, expressed as a function of r.

i. $r < R$

ii. $r > R$

(c) Is there any charge on the surface of the sphere ($r = R$)?

_____ Yes _____ No

If there is, determine the charge. In either case, explain your reasoning.

(d) On the axes below, sketch a graph of the force that would act on a positive test charge in the regions $r < R$ and $r > R$. Assume that a force directed radially outward is positive.