Chapter 12 Drill

The answers and explanations can be found in Chapter 17.

Section I: Multiple Choice

1. What will happen to the magnitude of electric force between two particles if the distance between them is doubled and each charge is tripled?

(A) It will be multiplied by a factor of $\frac{9}{4}$.

(B) It will be multiplied by a factor of $\frac{3}{2}$.

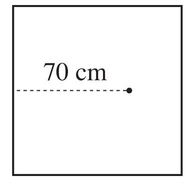
(C) It will be multiplied by a factor of $\frac{3}{4}$.

(D) It will be multiplied by a factor of $\frac{2}{3}$.

(E) It will be multiplied by a factor of $\frac{4}{9}$.

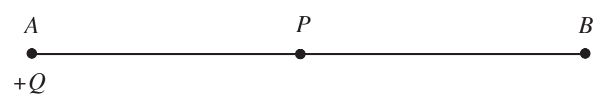
2. Two 1 kg spheres each carry a charge of magnitude 1 C. How does F_E, the strength of the electric force between the spheres, compare to F_G, the strength of their gravitational attraction?

(A) $F_E < F_G$
(B) $F_E = F_G$
(C) $F_E > F_G$
(D) If the charges on the spheres are of the same sign, then $F_E > F_G$; but if the charges on the spheres are of opposite sign, then $F_E < F_G$.
(E) Cannot be determined without knowing the distance between the spheres



3. The particle shown above is initially at rest inside a uniform electric field $E = 50$ N/C toward the left. The field area is a square with 1 m long sides. If the particle has a mass of 10^{-10} kg and a charge of $q = -5 \times 10^{-13}$ C, how long will it take the particle to escape the electric field?

(A) 1.10 s
(B) 1.23 s
(C) 1.55 s
(D) 2.31 s
(E) 2.59 s



4. Points A and B are equidistant from point P. At point A, there is a particle of charge $+Q$. This results in an electric field, E, at point P. If we want to triple the electric field at P, what charge should be placed at point B?

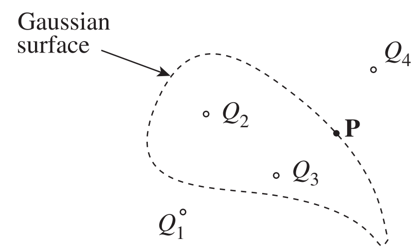
(A) $+3Q$
(B) $+2Q$
(C) $-Q$
(D) $-2Q$
(E) $-3Q$

5. A sphere of charge $+Q$ is fixed in position. A smaller sphere of charge $+q$ is placed near the larger sphere and released from rest. The small sphere will move away from the large sphere with
   (A) decreasing velocity and decreasing acceleration
   (B) decreasing velocity and increasing acceleration
   (C) decreasing velocity and constant acceleration
   (D) increasing velocity and decreasing acceleration
   (E) increasing velocity and increasing acceleration

6. A particle of negligible mass and charge $q = 1$ μC is fixed in place. A small object of mass $m = 10^{-3}$ kg and charge $q = 1$ μC is released from rest from a position 1 m directly above the particle. How far does the object fall before the electric force manages to push it away?
   (A) 0.1 m
   (B) 0.3 m
   (C) 0.5 m
   (D) 0.7 m
   (E) 0.9 m

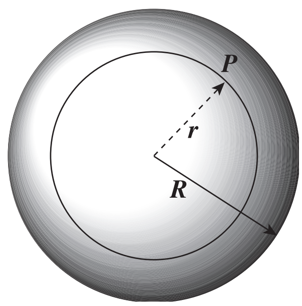
7. A conducting sphere of radius R has a charge of +Q. If the electric field at a point $2R$ from the center has an electric field of E, what is the electric field at a point $\frac{R}{2}$ from the center?
   (A) 0
   (B) $\frac{1}{4}E$
   (C) $\frac{1}{2}E$
   (D) $2E$
   (E) $4E$

8. The figure below shows four point charges and the cross section of a Gaussian surface:



Which of the following statements is true concerning the situation depicted?
   (A) The net electric flux through the Gaussian surface depends on all four charges shown, but the electric field at point P depends only on charges Q_2 and Q_3.
   (B) The net electric flux through the Gaussian surface depends only on charges Q_2 and Q_3, but the electric field at point P depends on all four charges.
   (C) The net electric flux through the Gaussian surface depends only on charges Q_2 and Q_3, and the electric field at point P depends only on charges Q_2, Q_3, and Q_4.
   (D) The net electric flux through the Gaussian surface depends only on charges Q_1 and Q_4, and the electric field at point P depends only on charges Q_2 and Q_3.
   (E) Both the net electric flux through the Gaussian surface and the electric field at point P depend on all four charges.

9. A nonconducting sphere of radius R contains a total charge of $-Q$ distributed uniformly throughout its volume (that is, the volume charge density, ρ is constant).



The magnitude of the electric field at Point P, at a distance $r < R$ from the sphere's center, is equal to

(A) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{R^3}r$

(B) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{R^2}r^2$

(C) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{R^3}r^3$

(D) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{R^3r^2}$

(E) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{Q}{r^2}$

10. Calculate the electric flux through a Gaussian surface of area A enclosing an electric dipole where each charge has magnitude q.

(A) 0
(B) $Aq/(4\pi\varepsilon_0)$
(C) $Aq^2/4\pi\varepsilon_0)$
(D) $Aq/(4\pi\varepsilon_0 r)$
(E) $Aq/(4\pi\varepsilon_0 r^2)$

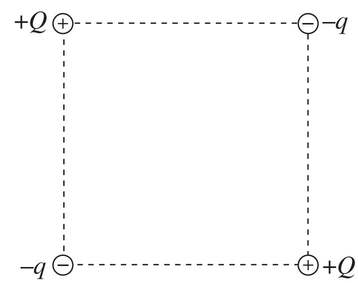
Section II: Free Response

1. In the figure shown, all four charges ($+Q$, $+Q$, $-q$, and $-q$) are situated at the corners of a square. The net electric force on each charge $+Q$ is zero.

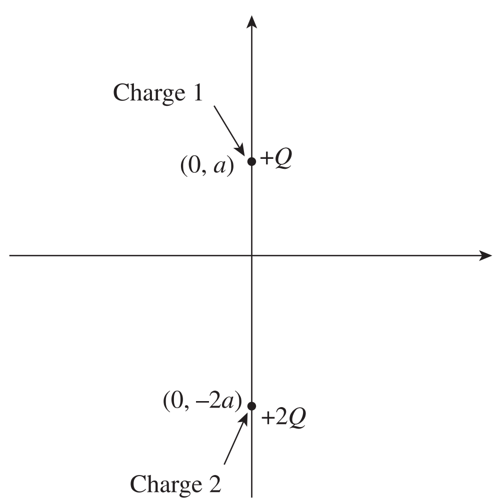
   (a) Express the magnitude of q in terms of Q.

   (b) Is the net electric force on each charge $-q$ also equal to zero? Justify your answer.

   (c) Determine the electric field at the center of the square.



2. Two charges, $+Q$ and $+2Q$, are fixed in place along the y-axis of an x-y coordinate system as shown in the figure below. Charge 1 is at the point $(0, a)$, and Charge 2 is at the point $(0, -2a)$.



   (a) Find the electric force (magnitude and direction) felt by Charge 1 due to Charge 2.

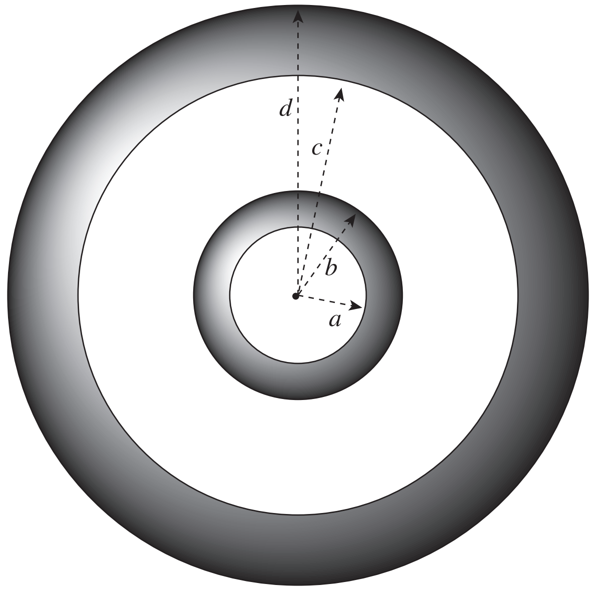
   (b) Find the electric field (magnitude and direction) at the origin created by both Charges 1 and 2.

   (c) Is there a point on the x-axis where the total electric field is zero? If so, where? If not, explain briefly.

   (d) Is there a point on the y-axis where the total electric field is zero? If so, where? If not, explain briefly.

   (e) If a small negative charge, $-q$, of mass m were placed at the origin, determine its initial acceleration (magnitude and direction).

3. A conducting spherical shell of inner radius a and outer radius b is inside (and concentric with) a larger conducting spherical shell of inner radius c and outer radius d. The inner shell carries a net charge of $+2q$, and the outer shell has a net charge of $+3q$.



(a) Determine the electric field for

(i) $r < a$

(ii) $a < r < b$

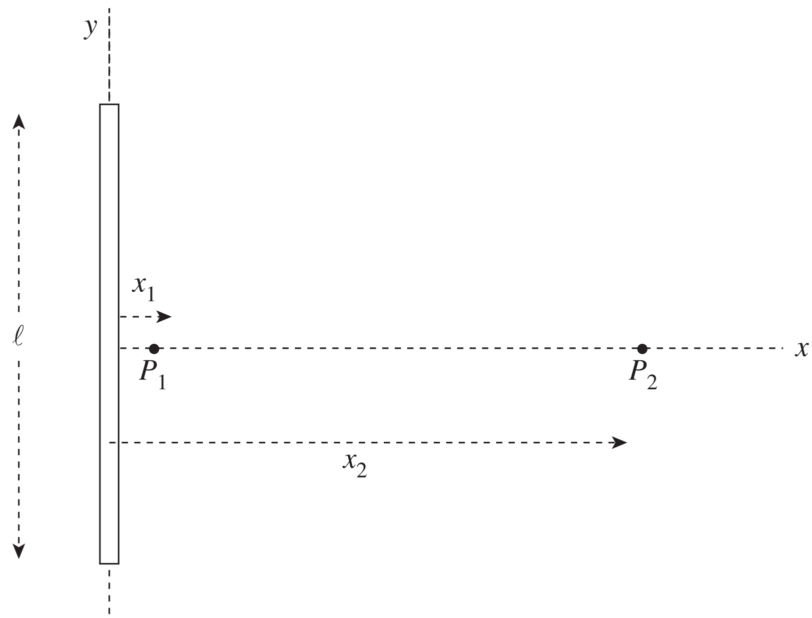
(iii) $b < r < c$

(iv) $c < r < d$

(v) $r > d$

(b) Show in the figure the charges that reside on or inside each of the two shells.

4. A positively charged, thin nonconducting rod of length ℓ lies along the y-axis with its midpoint at the origin. The linear charge density within the rod is uniform and denoted by λ. Points P_1 and P_2 lie on the positive x-axis, at distances x_1 and x_2, respectively from the rod.



(a) Use Gauss's law to approximate the electric field at point P_1, given that x_1 is very small compared to ℓ. Write your answer in terms of λ, x_1, and fundamental constants.

(b) What is the total charge Q on the rod?

(c) Compute the electric field at point P_2, given that x_2 is not small compared to ℓ. For $x_2 = \ell$, write your answer in terms of Q, ℓ, and fundamental constants. You may use the fact that

$$\int (x^2 + y^2)^{-3/2}\,dy = \frac{y}{x^2\sqrt{x^2 + y^2}} + c$$

5. A solid glass sphere of radius a contains excess charge distributed throughout its volume such that the volume charge density depends on the distance r from the sphere's center according to the equation

$$\rho(r) = \rho_s(r/a)$$

where ρ_s is a constant.

(a) What are the units of ρ_s?

(b) Compute the total charge Q on the sphere.

(c) Determine the magnitude of the electric field for

(i) $r < a$

(ii) $r \geq a$

Write your answers to both (i) and (ii) in terms of Q, a, r, and fundamental constants.

(d) Sketch the electric field magnitude E as a function of r on the graph below. Be sure to indicate on the vertical axis the value of E at $r = a$.