Questions 1-2
A 40 cm diameter Van de Graaff electrostatic generator has an electric potential of 200,000 V.

1) The electric field at the surface of the Van de Graaff is most nearly
A) 0
B) 5,000 N/C
C) 10,000 N/C
D) 500,000 N/C
E) 1,000,000 N/C

\[ E = \frac{kQ}{r^2}, \quad V = \frac{kQ}{r} \]

2) The excess charge on the Van de Graaff is most nearly
A) 4.4 x 10^-6 C
B) 8.9 x 10^-6 C
C) 4.4 x 10^-4 C
D) 8.9 x 10^-4 C
E) 3.6 x 10^14 C

3) A parallel plate capacitor X is connected to a 24 V battery. A second capacitor Y which has twice the area of capacitor X but is otherwise identical is connected to a 12 V battery. Which of the following quantities is greater for X than for Y?
A) capacitance
B) stored charge
C) stored energy
D) all of the above properties for X are less than for Y
E) all of the above properties for X and Y are equal in magnitude

\[ Q_x = \frac{CV_x}{V}, \quad Q_y = \frac{2CV_y}{V} \]

4) One joule of work is needed to move one coulomb of charge from one point to another with no change in velocity. Which of the following is true between the two points?
A) The resistance is one ohm.
B) The current is one ampere.
C) The potential difference is one volt.
D) The electric field strength is one newton per coulomb.
E) The electric field strength is one joule per electron.

5) A hollow metal sphere of radius R is positively charged. Of the following distances from the center of the sphere, which location will have the greatest electric field strength?
(A) O (center of the sphere)
(B) 3R/4
(C) 5R/4
(D) 2R
(E) None of the above because the field is of constant strength

6) Two positive charges of magnitude q are each a distance d from the origin A of a coordinate system as shown above.

At which of the following points is the electric field least in magnitude?
(A) A
(B) B
(C) C
(D) D
(E) E

7) At which of the following points is the electric potential greatest in magnitude?

\[ V = \frac{2kq}{r^2} \]

Questions 8-9
An electron is accelerated from rest for a time of 10^-9 second by a uniform electric field that exerts a force of 8.0 x 10^-15 newton on the electron.

8. What is the magnitude of the electric field?
(A) 8.0 x 10^-24 N/C
(B) 9.1 x 10^-22 N/C
(C) 8.0 x 10^-4 N/C
(D) 2.0 x 10^-5 N/C
(E) 5.0 x 10^-1 N/C

\[ F = qE = \frac{9e}{1.6 \times 10^{-19}} \]

9. The speed of the electron after it has accelerated for the 10^-9 second is mostly

\[ v = \sqrt{2a} \]

(A) 10^1 m/s
(B) 10^2 m/s
(C) 10^3 m/s
(D) 10^7 m/s
(E) 10^2 m/s

\[ a = \frac{F_e}{m} = \frac{9e}{9.11 \times 10^{-31}} \]
10. Two isolated charges, +q and -2q, are 2 centimeters apart. If \( F \) is the magnitude of the force acting on charge -2q, what are the magnitude and direction of the force acting on charge +q?

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Direction</th>
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<tbody>
<tr>
<td>( 1/2 ) ( F )</td>
<td>Toward charge -2q</td>
</tr>
<tr>
<td>( 1/2 ) ( F )</td>
<td>Away from charge -2q</td>
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<tr>
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<td>(E) ( 2F )</td>
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11. A positive charge of \( 10^{-6} \) coulomb is placed on an insulated solid conducting sphere. Which of the following is true?

(A) The charge resides uniformly throughout the sphere.
(B) The electric field inside the sphere is constant in magnitude, but not zero.
(C) The electric field in the region surrounding the sphere increases with increasing distance from the sphere.
(D) An insulated metal object acquires a net positive charge when brought near to, but not in contact with, the sphere.

When a second conducting sphere is connected by a conducting wire to the first sphere, charge is transferred until the electric potentials of the two spheres are equal.

12. Forces between two objects which are inversely proportional to the square of the distance between the objects include which of the following?

I. Gravitational force between two celestial bodies
II. Electrostatic force between two electrons
III. Nuclear force between two neutrons

(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

14. Which of the following is true about the net force on the uncharged conducting sphere in a uniform electric field?

(A) It is zero. It only polarizes but does not move.
(B) It is in the direction of the field.
(C) It is in the direction opposite to the field.
(D) It produces a torque on the sphere about the direction of the field.
(E) It causes the sphere to oscillate about an equilibrium position.

15. A parallel-plate capacitor is charged by connection to a battery. If the battery is disconnected and the separation between the plates is increased, what will happen to the charge on the capacitor and the voltage across it?

(A) Both remain fixed.
(B) Both increase.
(C) Both decrease.
(D) The charge increases and the voltage decreases.
(E) The charge remains fixed and the voltage increases.

Questions 16-17 relate to the five incomplete circuits below composed of resistors \( R \), all of equal resistance, and capacitors \( C \), all of equal capacitance. A battery that can be used to complete any of the circuits is available.

16. Into which circuit should the battery be connected to obtain the greatest steady power dissipation?

17. Which circuit will retain stored energy if the battery is connected to it and then disconnected?
18) A parallel-plate capacitor has a capacitance $C_0$. A second parallel-plate capacitor has plates with twice the area and twice the separation. The capacitance of the second capacitor is most nearly:

(A) $\frac{1}{4}C_0$
(B) $\frac{1}{2}C_0$
(C) $C_0$
(D) $2C_0$
(E) $4C_0$

19) Two capacitors are connected in parallel as shown above. A voltage $V$ is applied to the pair. What is the ratio of charge stored on $C_2$ to the charge stored on $C_1$, when $C_1 = 1.5C_2$?

(A) $\frac{4}{9}$
(B) $\frac{2}{3}$
(C) $\frac{2}{3}$
(D) $\frac{3}{2}$
(E) $\frac{9}{4}$

20) Two large parallel conducting plates P and Q are connected to a battery of emf $C$, as shown above. A test charge is placed successively at points I, II, and III. If edge effects are negligible, the force on the charge when it is at point III is:

(A) of equal magnitude and in the same direction as the force on the charge when it is at point I
(B) of equal magnitude and in the same direction as the force on the charge when it is at point II
(C) equal in magnitude to the force on the charge when it is at point I, but in the opposite direction
(D) much greater in magnitude than the force on the charge when it is at point II, but in the same direction
(E) much less in magnitude than the force on the charge when it is at point II, but in the same direction
872. Object I, shown above, has a charge of $+3 \times 10^{-6}$ coulomb and a mass of 0.0025 kilogram.

a. What is the electric potential at point P, 0.30 meter from object I?

$$V = k\frac{Q}{r} = \frac{(9 \times 10^9)(3 \times 10^{-6})}{0.3} = 90000 \text{ V}$$

Object II, of the same mass as object I, but having a charge of $+1 \times 10^{-6}$ coulomb, is brought from infinity to point P, as shown above.

b. How much work must be done to bring the object II from infinity to point P?

$$W = \varphi V = (1 \text{ e-6})(9 \times 4) = 0.09 \text{ J}$$

c. What is the magnitude of the electric force between the two objects when they are 0.30 meter apart?

$$F_e = \frac{kQ_1Q_2}{r^2} = \frac{(9 \times 10^9)(1 \text{ e-6})(3 \text{ e-6})}{(0.3)^2} = 0.3 \text{ N}$$

d. What are the magnitude and direction of the electric field at the point midway between the two objects?

$$E = E_1 - E_2 = \frac{kQ_1}{r^2} - \frac{kQ_2}{r^2} = \frac{k}{r^2}(Q_1 - Q_2) = 4 \times 10^5 \text{ N/C} \text{ to the right}$$

The two objects are then released simultaneously and move apart due to the electric force between them. No other forces act on the objects.

e. What is the speed of object I when the objects are very far apart?

$$P_1 = P_{2N}$$

Since $m_1 = m_{2N}$, then $V_1 = V_{2N}$

$$\vec{E}_B = \vec{E}_{2A}$$

$$U_B = K_1 + K_2$$

$$U_B = mV^2$$

$$V = \sqrt{\frac{U}{m}} = \frac{0.9}{0.025} = 6 \text{ m/s}$$
1B.3. Four charged particles are held fixed at the corners of a square of side $s$. All the charges have the same magnitude $Q$, but two are positive and two are negative. In Arrangement 1, shown above, charges of the same sign are at opposite corners. Express your answers to parts a. and b. in terms of the given quantities and fundamental constants.

a. For Arrangement 1, determine the following.

i. The electrostatic potential at the center of the square

$$ V = \frac{kQ}{r} = \frac{kQ}{s} = \frac{kQ}{s}$$

b. For Arrangement 2, determine the following.

i. The electrostatic potential at the center of the square

$$ V = k \frac{Q}{r} = k \frac{Q}{\frac{s\sqrt{2}}{2}} = k \frac{Q}{\frac{s\sqrt{2}}{2}}$$

c. In which of the two arrangements would more work be required to remove the particle at the upper right corner from its present position to a distance a long way away from the arrangement?

Arrangeement 1

Arrangeement 2

Justify your answer

- The force of attraction is greater in Arrangement 1.
The diagram above shows some of the equipotentials in a plane perpendicular to two parallel charged metal cylinders. The potential of each line is labeled.

(a) The left cylinder is charged positively. What is the sign of the charge on the other cylinder?

(b) On the diagram above, sketch lines to describe the electric field produced by the charged cylinders.

(c) Determine the potential difference, $V_A - V_B$, between points $A$ and $B$.

(d) How much work is done by the field if a charge of 0.10 coulomb is moved along a path from point $A$ to $B$ and then to point $D$?

(a) +

(b) see drawing

(c) $V_A - V_B = -20 - 10 = -30 V$

(d) $W = \Delta V_e = \Delta V_q = (30)(0.5) = 15 J$
98B2. A wall has a negative charge distribution producing a uniform horizontal electric field. A small plastic ball of mass 0.01 kg, carrying a charge of -80.0 \mu C is suspended by an uncharged, nonconducting thread 0.30 m long. The thread is attached to the wall and the ball hangs in equilibrium, as shown above, in the electric and gravitational fields. The electric force on the ball has a magnitude of 0.032 N.

a. On the diagram below, draw and label the forces acting on the ball.

\[ E = \frac{F_e}{q} = \frac{0.032}{-8 \times 10^{-6}} = 400 \, \text{N/C} \ \text{in} \ -x \ \text{direction} \]

\[ \text{or} \]

\[ \text{toward wall} \]

b. Calculate the magnitude of the electric field at the ball's location due to the charged wall, and state its direction relative to the coordinate axes shown.

\[ \tan \theta = \frac{F_e}{mg} \]

\[ \theta = \tan^{-1} \left( \frac{0.032}{0.093} \right) = 18.1^\circ \]

\[ x = 0.3 \times \sin \theta = 0.093 \, \text{m} \]

c. Determine the perpendicular distance from the wall to the center of the ball.

d. The string is now cut. Calculate the magnitude of the resulting acceleration of the ball,

\[ \sum F = ma \]

\[ a = \frac{\sum F}{m} \]

\[ a = \frac{0.032 + 0.093 \times 0.01}{0.01} = 10.3 \, \text{m/s}^2 \]
In a television set, electrons are first accelerated from rest through a potential difference in an electron gun. They then pass through deflecting plates before striking the screen.

a. Determine the potential difference through which the electrons must be accelerated in the electron gun in order to have a speed of \(6.0 \times 10^7\) m/s when they enter the deflecting plates.

\[
\begin{align*}
E_1 &= E_x \\
K &= V_x = V_e \\
\frac{1}{2}mv^2 &= V_e \\
v &= \frac{mv^2}{2e} = 10,280\, V
\end{align*}
\]

The pair of horizontal plates shown below is used to deflect electrons up or down in the television set by placing a potential difference across them. The plates have length 0.04 m and separation 0.012 m, and the right edge of the plates is 0.50 m from the screen. A potential difference of 200 V is applied across the plates, and the electrons are deflected toward the top of the screen. Assume that the electrons enter horizontally midway between the plates with a speed of \(6.0 \times 10^7\) m/s and that fringing effects at the edges of the plates and gravity are negligible.

![Diagram of deflecting plates](image)

Note: Figure not drawn to scale.

b. Which plate in the pair must be at the higher potential for the electrons to be deflected upward? Check the appropriate box below.

- [ ] Upper plate
- [ ] Lower plate

Justify your answer.

\[\text{\(e^-\) is attracted to \(+\) plate and \(\vec{E}\) field is down \(\downarrow\)}\]

c. Considering only an electron's motion as it moves through the space between the plates, compute the following.

i. The time required for the electron to move through the plates

\[
V_x = \text{constant} = \frac{Ax}{At} \quad \Delta t = \frac{Ax}{V_x} = \frac{0.04}{6 \times 10^7} = 6.7 \times 10^{-10} \text{ s}
\]

ii. The vertical displacement of the electron while it is between the plates

\[
y = \frac{1}{2}at^2 \quad F = ma \quad a = \frac{V_e}{0.012} = \frac{200(1.6 \times 10^{-19})}{0.012(1.6 \times 10^{-3})} = 2.93 \times 10^7 \text{ m/s}^2
\]

\[
y = \frac{1}{2}at^2 = 6.57 \times 10^{-4} \text{ m}
\]

da. Show why it is a reasonable assumption to neglect gravity in part c.

\[
\frac{F_1}{F_2} \gg \frac{\gamma + m_g}{\gamma} \gg 2.6 \times 10^{-5} \gg 9.99 \times 10^{-30}
\]

e. Still neglecting gravity, describe the path of the electrons from the time they leave the plates until they strike the screen. State a reason for your answer.

\[\text{see diagram}\]

parabola \(\Rightarrow\) accelerating 
linear \(\Rightarrow \) constant \(v\)
2B5B. (10 points) Two parallel conducting plates, each of area 0.30 m$^2$, are separated by a distance of $2.0 \times 10^{-2}$ m of air. One plate has charge $+Q$, the other has charge $-Q$. An electric field of 5000 N/C is directed to the left in the space between the plates, as shown in the diagram above.

(a) Indicate on the diagram which plate is positive (+) and which is negative (−).

(b) Determine the potential difference between the plates.

$$V = E \cdot d = 5000(2E-2) = 100V$$

(c) Determine the capacitance of this arrangement of plates.

$$C = \frac{\varepsilon_0 A}{d} = \frac{(1.85 \times 10^{-12})(0.3)}{2E-2} = 1.3E-10 F$$

An electron is initially located at a point midway between the plates.

(d) Determine the magnitude of the electrostatic force on the electron at this location and state its direction.

$$F_e = E \cdot q = 5000(1.6E-19) = 8E-16 N \text{ to the right}$$

(e) If the electron is released from rest at this location midway between the plates, determine its speed just before striking one of the plates. Assume that gravitational effects are negligible.

$$F_e = ma$$

$$a = \frac{F_e}{m} = \frac{8E-16}{9.11 \times 10^{-31}} = 8.78 \times 10^9 \text{ m/s}^2$$

$$v^2 = v_0^2 + 2a(x-x_0)$$

$$v = \sqrt{2ax} = 8.7 \times 10^4 \text{ m/s}$$