Q1.
Three charges, \( q_1 = q_2 = 2.0 \ \mu C \) and \( Q = 4.0 \ \mu C \), are fixed in their places as shown in Figure 1. Find the net electrostatic force on \( Q \) due to \( q_1 \) and \( q_2 \). \( \hat{i} \) and \( \hat{j} \) are the unit vectors in the direction of \( x \) and \( y \), respectively.

![Diagram of three charges](image)

- A) \((0.46 \hat{i}) \text{ N}\)
- B) \((0.17 \hat{i}) \text{ N}\)
- C) \((0.46 \hat{i} + 0.17 \hat{j}) \text{ N}\)
- D) \((0.17 \hat{i} - 0.46 \hat{j}) \text{ N}\)
- E) \((0.17 \hat{i} + 0.32 \hat{j}) \text{ N}\)

**Answer**

Magnitude of \( \text{F}_{Qq1} = \text{magnitude of F}_{Qq2} = 0.288 \text{ N}\)

Their y-components will cancel and so \( (\text{F}_x)_{\text{net}} = 2 \times 0.288 \times (0.4/0.5) = 0.46 \text{ N} \) in the positive x-direction.

\( q_1 = 2 \times 10^{-6} \); \( Q = 4 \times 10^{-6} \); \( k = 9 \times 10^9 \); \( x = .4 \); \( y = .3 \); \( d = 0.5 \);

\[ \mathbf{F} = 2k \frac{q_1 Q x}{d^2} \quad / / \text{ N} \]

0.4608

Q2.
Two charges, \( q_1 = +5.0 \text{ nC} \) and \( q_2 = -10 \text{ nC} \), are shown in Figure 2. In which region (or regions) can the net electric field due to the two charges be zero?

![Diagram of two charges](image)
A) III  
B) II  
C) I  
D) I and II  
E) II and III

Q3.  
Two point charges, \( q_1 = -4.5 \, \text{nC} \) and \( q_2 = +4.5 \, \text{nC} \), are separated by 3.1 mm and forming an electric dipole. The charges are in a uniform electric field whose direction makes an angle of 37° with the line connecting the charges. Find the magnitude of this electric field, in N/C, if the torque exerted on the dipole has magnitude of \( 7.2 \times 10^{-9} \, \text{N.m} \).

A) 8.6 \times 10^2  
B) 5.6 \times 10^3  
C) 2.3 \times 10^4  
D) 9.9 \times 10^3  
E) 4.5 \times 10^2

Answer:

\[ \tau = pE \sin 37^\circ = qdE \sin 37^\circ = qd \frac{\tau}{qd \sin 37^\circ} = 0.857 \times 10^3 = 8.6 \times 10^2 \, \text{N/C} \]

Q4.  
An electron is released from rest in a uniform electric field. The electron accelerates vertically upward, travelling 4.50 m in the first 3.00 micro second after it is released. What are the magnitude and direction of the electric field? [Note: Neglect the gravitational force]

A) 5.69 N/C downward  
B) 5.69 N/C upward  
C) 8.24 N/C upward  
D) 8.24 N/C downward  
E) 4.30 N/C downward

Answer:

\[ F = qE, \text{ The force on the electron will be in the opposite direction to E so E must be in the downward direction to start with.} \]

\[ Y = \frac{1}{2} at^2 = \frac{1}{2} qEt^2/m_e \Rightarrow E = (2y/m_e)/(qt^2) = (2 \times 4.5 \times 9.1 \times 10^{-31})/ (1.6 \times 10^{-19} \times (3 \times 10^{-6})^2) = 5.687 \, \text{N/C (DOWNWARD)} \]

Q5.  
A 2.6 µC charge is at the center of a cube 7.0 cm on each side. What is the electric flux, in kN.m^2/C, through one face of the cube?

A) 49  
B) 24  
C) 12  
D) 89  
E) Zero
Answer:
The symmetry of the situation guarantees that the flux through one face is 1/6 the flux through the whole cubical surface, so
\[ \Phi_e = \frac{Q_{net}}{6\varepsilon_o} = \frac{2.6 \times 10^{-6}}{6 \times 8.85 \times 10^{-12}} = 48.96 \times 10^3 \]

Q6.

Figure 3 shows a pyramid with horizontal square base, \( a = 6.00 \text{ m} \) on each side, and a height, \( h = 4.00 \text{ m} \). The pyramid is placed in an upward vertical electric field of magnitude \( E = 52.0 \text{ N/C} \). If the pyramid does not include any charge inside, calculate the electric flux, in N.m\(^2\)/C, through its four slanted (inclined) surfaces.

Fig#  

A) \( +1.87 \times 10^3 \)  
B) \( -1.87 \times 10^3 \)  
C) \( +0.9 \times 10^3 \)  
D) \( -0.9 \times 10^3 \)  
E) \( -3.27 \times 10^3 \)

Answer:
The total electric flux through the pyramid, \( \Phi_{E,\text{square}} + \Phi_{E,\text{4slanted}} \), vanishes since the electric field is constant and no charges inside it. Thus the flux through the four slanted surfaces is, up to the sign, the same as through the square base:
\[ \Phi_{E,\text{square}} = EA \cos 180^\circ = 52 \times 6^2 \approx -1.872 \times 10^3 \text{ Nm}^2 \text{ C} = -1.872 \times 10^3 \text{ Vm}. \]
then
\[ \Phi_{E,4\text{slanted}} = 1.872 \times 10^3 \text{ Vm} \]

Q7.

Figure 4 show an infinitely long line of charge having a uniform charge per unit length \( \lambda \). The line lies at a normal distance \( d \) from the center of a sphere of radius \( R \) (\( d < R \)). Determine the total electric flux through the surface of the sphere resulting from this line charge.

Fig#
A) \( \frac{2\lambda \sqrt{R^2 - d^2}}{\varepsilon_0} \)
B) \( 4\lambda \sqrt{R^2 - d^2} \)
C) \( \frac{\lambda \sqrt{R^2 - d^2}}{2\varepsilon_0} \)
D) \( \frac{\lambda \sqrt{R^2 - d^2}}{\varepsilon_0} \)
E) \( 2\lambda \left( R^2 - d^2 \right) \)

Answer:
\( \Phi_e = \frac{Q_{enc}}{\varepsilon_0} = \frac{2\lambda \sqrt{R^2 - d^2}}{\varepsilon_0} \)

Q8.
Figure 5 shows sections of three infinitely flat thin insulating charge sheets, each carrying surface charge density of magnitude \( \sigma \). Find the magnitude of the electric field in region 3.

A) \( 3\sigma/2\varepsilon_0 \)
B) \( \sigma/2\varepsilon_0 \)
C) $3\sigma/\varepsilon_0$
D) $\sigma/\varepsilon_0$
E) $\sigma/3\varepsilon_0$

**Answer:**

\[ E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{3\sigma}{2\varepsilon_0} \]

**Q9.**

An insulating spherical ball of radius 4.0 cm has $-40 \, \mu\text{C}$ charge uniformly distributed throughout the volume. Find the magnitude and direction of the electric field at a point 2.0 cm from its center.

A) $1.13 \times 10^8 \, \text{N/C}$ towards the center
B) $1.13 \times 10^8 \, \text{N/C}$ away from the center
C) $0.45 \times 10^8 \, \text{N/C}$ towards the center
D) $0.45 \times 10^8 \, \text{N/C}$ away from the center
E) $3.23 \times 10^8 \, \text{N/C}$ towards the center

**Answer:**

\[ q = 40 \times 10^{-6} \, \text{C}; \, d = 4 \, \text{cm}; \, k = 9 \times 10^9 \, \text{N} \cdot \text{m}^2/\text{C}^2; \, r = 2 \, \text{cm} \]

**Q10.**

Two charged particles, $q_1$ and $q_2$, are fixed on the x-axis. $q_1$ is fixed at the origin and $q_2$ is fixed on the positive x-axis and at a distance $d$ from the origin. It is found that the electric field is zero at $x = d/3$. Choose the correct answer.

A) The electric potential is never be zero except at infinity
B) The electric potential would be zero at $x = -d/2$
C) The electric potential would be zero at $x = 4d$
D) The electric potential would be zero at $x = d/2$
E) The electric potential would be zero at $x = -d/6$

**Q11.**

Four identical charged particles, each of charge $q = 30 \, \mu\text{C}$, are fixed at the corners of a square of length 10.0 cm. How much work is required, by an external agent, to move one of them to infinity?

A) $-219 \, \text{J}$
B) $+219 \, \text{J}$
C) $-510 \, \text{J}$
D) $+105 \, \text{J}$

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Q12. \textbf{Figure 6} shows two parallel plates separated by a vertical distance of \(d = 0.2\) m. The potentials at the upper and lower plates are 100 V and 900 V, respectively. A particle, of mass \(m = 0.1\) kg and charge \(q = -500\) µC, was released from rest, downwards, from the upper plate. What is the kinetic energy of the particle when it reaches the lower plate?

\[ W_1 = 2 \frac{kq^2}{d} + \frac{kq^2}{\sqrt{2}d} - \left( 4 \frac{kq^2}{d} + k \frac{2q^2}{\sqrt{2}d} \right) \\
= -219.276 \]

(* another solution *)

\[ W_2 = -2 \frac{kq^2}{d} - k \frac{q^2}{\sqrt{2}d} \\
= -219.276 \]

A) 0.6 J  
B) 1.5 J  
C) 0.2 J  
D) 3.1 J  
E) 0.4 J

**Answer:**

\[ \Delta K = W_{\text{app}} + W_{\text{field}} \]

\[ \Delta K = mgd - qV = 0.1 \times 9.8 \times 0.21 + 500 \times 10^{-6} \times 800 = 0.606 \text{ J} \]

Q13. The graph (\textbf{Figure 7}) shows how the charge of a capacitor varies with the potential difference across it. Use the graph to find the energy stored in the capacitor when the potential difference across it is 12 V.

**Answer:**
A) 32 µJ  
B) 63 µJ  
C) 17 µJ  
D) 23 µJ  
E) 48 µJ  

Answer:

\[ C = \frac{\Delta Q}{\Delta V} = \text{slope of the Q–V graph} = \frac{3.5 \times 10^{-6} - 0}{8.0 - 0} \]
\[ = 4.4 \times 10^{-7} \text{ F} = 0.44 \mu\text{F}. \]
\[ U = \frac{1}{2} CV^2 = \frac{1}{2} (4.4 \times 10^{-7})(12)^2 = 32 \times 10^{-6} \text{ J} = 32 \mu\text{J}. \]

Q14.

Two capacitors, \( C_1 \) and \( C_2 \) are connected in series to a 40 V power supply. If the capacitance of \( C_1 = 35 \text{ nF} \), and of \( C_2 = 85 \text{ nF} \), find the voltage across \( C_1 \).

A) 28 V  
B) 12 V  
C) 16 V  
D) 40 V  
E) 24 V  

Answer:

Capacitors in series have the same charge, but different potentials depending on their capacitances such that the sum of the two potentials equals to the voltage of the power supply.

Since \( Q_1 = Q_2 \) and \( V = V_1 + V_2 \) \( \Rightarrow \) \( C_1V_1 = C_2V_2 = C_3(V - V_1) \)
\( \Rightarrow \) \( V_1 = C_2V/(C_1 + C_2) = (85 \times 40)/(35 + 85) = 28.33 \text{ V} \)

Q15.

Figure 8 shows 6 identical capacitors, each with a capacitance of 1.0 µF. Find the equivalent capacitance \( C_{eq} \) between points A and B.

Fig#
A) 1.5 µF
B) 4.0 µF
C) 3.0 µF
D) 2.5 µF
E) 9.0 µF

Answer:

$C_{123} = 3C_1$ they are in parallel; $C_{456} = 3C_1$; they are in parallel. $C_{123}$ and $C_{456}$ are in series. So,

$C_{eq} = \frac{C_{123} \times C_{456}}{C_{123} + C_{456}} = \frac{9}{6} = 1.5$

Q16.
An air-filled parallel plate capacitor has a capacitance of 5.0 µF and a plate area of 60 cm$^2$. What is the energy density stored, in J/m$^3$, between the plates if the potential difference across them is 8.0 V?

A) $2.5 \times 10^6$
B) $5.0 \times 10^5$
C) $1.2 \times 10^6$
D) $1.6 \times 10^6$
E) $8.9 \times 10^5$

Answer:

$C = \varepsilon_o A/d \Rightarrow d = \varepsilon_o A/C$

$u = \frac{1}{2} \varepsilon_o E^2 = \frac{1}{2} \varepsilon_o \left(\frac{V}{d}\right)^2 = \frac{1}{2} \varepsilon_o \left[\frac{V}{(\varepsilon_o A/C)}\right]^2 = \frac{1}{2} \left(CV/A\right)^2/(\varepsilon_o) = 2.5 \times 10^6$ J/m$^3$.

or

$u = U / (Volume) = (\frac{1}{2}CV^2) / (Ad) = (\frac{1}{2}CV^2)/(A\varepsilon_o A/C) = \frac{1}{2}(C^2V^2/A^2)/\varepsilon_o = 2.5 \times 10^6$ J/m$^3$.

Q17.
An air-filled parallel plate capacitor with a plate area of 12 cm$^2$ and a separation of 1.5 mm is connected to a battery. What happens if the gap is filled completely with mica of a dielectric constant 4.0 while the battery is connected?

A) The energy stored in the capacitor increases.
B) The energy stored in the capacitor decreases.
C) The energy stored in the capacitor remains the same.
D) The voltage across the capacitor increases.
E) The voltage across the capacitor decreases.

**Answer:**
Since the battery is continue connected to the capacitor then the voltage across the capacitor remains the same since the battery is creating that potential difference across it, but the capacitance increases if a dielectric material is inserted between the plates instead of air which force the battery to send more charge to the plates. Then \( U = \frac{1}{2} CV^2 = \frac{1}{2} \kappa C \omega^2 = \kappa U_o > U_o \)

Q18.
At what temperature will aluminum have a resistivity that is three times the resistivity that of copper has at 20 °C? At 20 °C, the resistivity of aluminum is 2.75×10⁻⁸ Ω·m and the resistivity of copper is 1.69×10⁻⁸ Ω·m. The temperature coefficient of aluminum \( \alpha_{Al} = 4.4 \times 10^{-3} \text{ K}^{-1} \).

A) 212 °C  
B) 250 °C  
C) 130 °C  
D) 600 °C  
E) 420 °C

**Answer:**

\[
\rho_{Al} = \rho_{Al0}[1 + \alpha_{Al}(T - T_0)].
\]

Setting \( \rho_{Al} = 3\rho_{Cu0} \) and solving for \( T \) we obtain
\[
T = \frac{3\rho_{Cu0} - \rho_{Al0}}{\alpha_{Al}\rho_{Al0}} + T_0 = \frac{3(1.69 \times 10^{-8} \text{ \Omega \cdot m}) - 2.75 \times 10^{-8} \text{ \Omega \cdot m}}{(4.4 \times 10^{-3} \text{ \text{K}^{-1}})(2.75 \times 10^{-8} \text{ \Omega \cdot m})} + 20\text{ °C} = 211.7\text{ °C}.
\]

\( T_0 = 20; \rho_{Al} = 2.75 \times 10^{-8}; \rho_{Cu} = 1.69 \times 10^{-8}; \alpha_{Al} = 4.4 \times 10^{-3}; \)

Solve \( 3\rho_{Cu} - \rho_{Al}(1 + \alpha_{Al}(T-T_0)) = 0, T \)

\( T = 211.736 \)

Q19.
A continuous beam of electrons, of current 125 mA, is incident on a target. How many electrons strike the target in a period of 23.0 s?

A) 1.80×10¹⁹  
B) 1.37×10¹⁹  
C) 7.21×10¹⁹
D) \(2.16 \times 10^{19}\)
E) \(1.56 \times 10^{19}\)

Answer:

\[ n_p = \frac{Q}{q_p} = \frac{I \Delta t}{q_p} = \frac{(125 \times 10^{-3} \, \text{A})(23.0 \, \text{s})}{1.6 \times 10^{-19} \, \text{C}} = 1.797 \times 10^{19} \]

\[ I_i = 125 \times 10^{-3}; \quad e_e = 1.6 \times 10^{-19}; \quad t_i = 23; \]

\[ N_e = \frac{I_i t_i}{e_e} \]

\[ 1.79687 \times 10^{19} \]

Q20.
A light bulb, has a resistance of 15 \(\Omega\), is connected between the terminals of a 120 V source. **If the temperature is not ignored**, which one of the following answers can be the expected output power of the bulb?

A) 940 W
B) 960 W
C) 1000 W
D) 1800 W
E) 5000 W

Answer:

If the effect of temperature is ignored, the power generated would be

\[ P = \frac{V^2}{R} = \frac{(120 \, \text{V})^2}{15 \, \Omega} = 960 \, \text{W}. \]

However, the resistance of the bulb filament increases with temperature, making the output power less than 960 W. The only possible output is therefore 940 W.