Q1.

Two identical small conducting spheres, separated by a center-to-center distance of 20.0 cm, have equal electric charge. The distance between the spheres centers is very large compared to the spheres radii. How many excess electrons must be present on each sphere if the magnitude of the force of repulsion between them is 3.33 × 10^{-21} N?

A) 760
B) 513
C) 322
D) 855
E) 411

Ans:

$$q = \sqrt{\frac{Fd^2}{k}} = \sqrt{\frac{3.33 \times 10^{-21} \times (0.2)^2}{9 \times 10^9}} = 1.2166 \times 10^{-16}\text{C}$$

$$q = ne$$

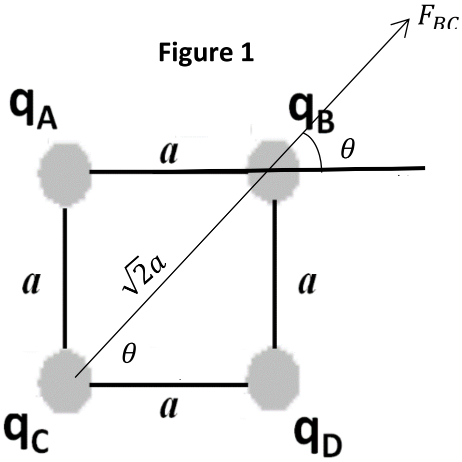
$$n = \frac{q}{e} = \frac{1.2166 \times 10^{-16}}{1.6 \times 10^{-19}} = 760.4$$

Q2.

Four point charges q_A, q_B, q_C, q_D are at the corners A, B, C and D of a square, with q_B and q_C on opposite corners have equal charge of +1.5 C, as shown in **Figure 1**. Charges q_A, q_D, on the other two corners, have equal charge. What is the charge q_A so that the net force on q_B is zero?

A) −0.53 C
B) −1.0 C
C) −0.35 C
D) −1.7 C
E) −0.88 C

Figure 1



Ans:

$$\vec{F}_{net-q_B} = F_x\vec{\imath} + F_y\vec{\jmath} = 0 \implies |F_x| = |F_y| = 0$$

$$F_x = F_{BA} + F_{BC}\cos 45 = 0$$

$$F_{BC}\cos 45 = -F_{BA}$$

$$\frac{kq_Bq_C}{2a^2}\cos 45 = \frac{-kq_Aq_B}{a^2} = \frac{k_1|q_{A1}||q_{B1}|}{a^2}(q_A\ is\ negative)$$

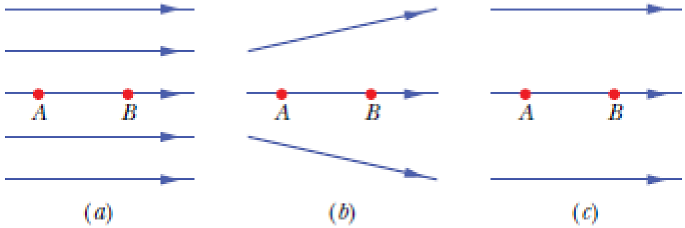
$$|q_A| = \left|\frac{q_c}{2}\right|\cos 45 = \frac{1.5 \times \cos 45}{2} = 0.53 \times \text{C}$$

$$q_A = -0.53\ \text{C}$$

Q3.

Figure 2 shows three arrangements of electric field lines. In each arrangement, a proton is released from rest at point *A* and is then accelerated through point *B* by the electric field. Points *A* and *B* have equal separations in the three arrangements. Rank the arrangements according to the linear momentum of the proton at point *B*, greatest first.

Figure 2



A) a, b, c
B) b, c, a
C) c, b, a
D) a, c, b
E) c, a, b

Ans:

A

Q4.

How much work is required to rotate an electric dipole 120° from its initial direction in a uniform electric field of magnitude E = 72.0 N/C if the dipole moment p = 2.51×10^{-25} C.m. The initial angle between the dipole moment and the electric field is 60.0°?

A) 2.71×10^{-23} J
B) 3.11×10^{-23} J
C) 4.55×10^{-23} J
D) 1.17×10^{-23} J
E) 5.80×10^{-23} J

Ans:

$$W_a = \Delta U = -pE\left(cos\theta_f - cos\theta_i\right)$$

$$= -2.5\times10^{-25}\times 72(cos180 - cos60)$$

$$W_a = 2.7\times10^{-23}\ \text{J}$$

Q5.

A proton initially moves along the positive x axis at a speed of 3.5 × 10^3 m/s. It then enters into a region with an electric field in the negative x direction. The proton travels a distance of 0.20 m before coming to rest. What is the magnitude of the electric field?

A) 0.32 N/C
B) 0.93 N/C
C) 0.85 N/C
D) 0.16 N/C
E) 0.55 N/C

Ans:

$$a = \frac{qE}{m_p}; a = \frac{-v_i^2}{2\Delta x}(v_f = 0) \Longrightarrow$$

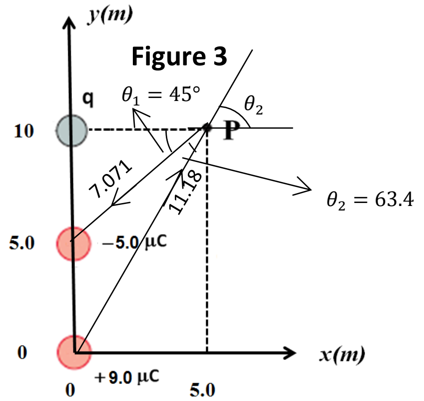
$$considering\ magnitude$$

$$\frac{qE}{m_p} = \frac{v_i^2}{2\Delta x} \Longrightarrow E = \frac{v_i^2 \times m_p}{2q\Delta x} = \frac{(3.5 \times 10^3)^2 \times 1.673 \times 10^{-27}}{2 \times 1.6 \times 10^{-19} \times 0.2} = 0.32\ \text{N/C}$$

Q6.

As shown in **Figure 3** three charges + 9.0 μC, –5.0 μC and q, are placed along y axis. If the net electric field E at the point P due to these charges points in the y direction, determine the charge q?

A) + 0.95 μC
B) – 0.22 μC
C) + 0.34 μC
D) – 0.95 μC
E) + 0.22 μC



Ans:

$$Since\ x\ component\ of\ E_{net} = 0$$

$$E_x = k\left[\frac{q}{5^2} - \frac{5 \times cos45}{(7.01)^2} + \frac{9 \times \cos 63.4}{(11.18)^2}\right] \times 10^{-6} = 0$$

$$q = 5^2\left(\frac{5 \times cos45}{(7.01)^2} - \frac{9 \times \cos 63.4}{(11.18)^2}\right)\mu C = 0.9506 \times 10^{-6}\ \text{C}$$

Q7.

A point charge is located at the center of a Gaussian spherical surface. If the charge is doubled and the radius of the surface is also doubled, which of the following statements describe correctly the changes in electric flux Φ_E and electric field E at the Gaussian spherical surface?

A) Φ_E increases and *E* decreases.
B) Φ_E and *E* do not change.
C) Φ_E increases and *E* remains the same.
D) Φ_E increases and *E* increases.
E) Φ_E decrease and *E* decreases.

Ans:

A

Q8.

The magnitude of the electric field of a very long uniformly charged cylindrical wire at a radial distance of 5.0 cm from the wire axis is 2.0×10^3 N/C. If the field points radially toward the wire axis, what is the magnitude of the charge on a 10 cm long segment of the wire?

A) 0.56 nC
B) 0.11 nC
C) 2.6 nC
D) 1.8 nC
E) 3.1 nC

Ans:

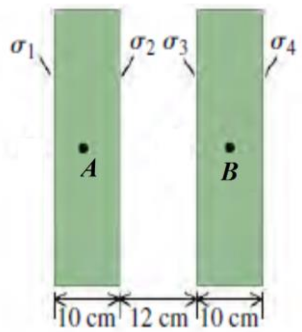
$$\lambda = \frac{E \cdot r}{2k} = \frac{q}{l}$$

$$q = \frac{l \times E \times r}{2 \times k} = \frac{0.1 \times 2000 \times 0.05}{2 \times 9 \times 10^9} = 0.556 \times 10^{-9}\ \mathrm{C}$$

Q9.

Two very large, non-conducting plastic sheets, each 10 cm thick, carry uniform surface charge densities σ_1, σ_2, σ_3, and σ_4 on their surfaces, as shown in **Figure 4**. These surface charge densities have values $\sigma_1 = -3.5\ \mu C/m^2$, $\sigma_2 = +3.0\ \mu C/m^2$, $\sigma_3 = +1.5\ \mu C/m^2$, and $\sigma_4 = -2.5\ \mu C/m^2$. Find the magnitude of the ratio (E_A/E_B) of the electric field E_A at the points A to that E_B at the point B far from the edges of these sheets:

Figure 4



A) 1.6
B) 2.3
C) 1.0
D) 2.8
E) 3.8

Ans:

$$E_A = \frac{1}{2\varepsilon_0}[-|\sigma_1| - |\sigma_2| - |\sigma_3| + |\sigma_4|]$$

$$= \frac{1}{2\varepsilon_0}[-3.5 - 3.0 - 1.5 + 2.5] \times 10^{-6} = -\frac{5.5 \times 10^{-6}}{2\varepsilon_0}$$

$$E_B = \frac{1}{2\varepsilon_0}[-|\sigma_1| + |\sigma_2| + |\sigma_3| + |\sigma_4|]$$

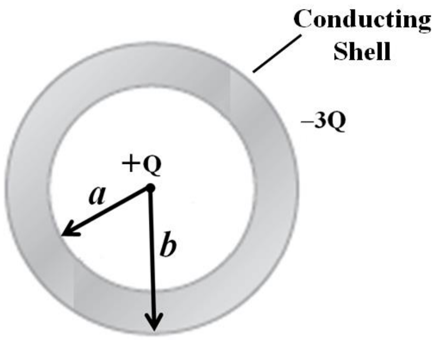
$$= \frac{1}{2\varepsilon_0}[-3.5 + 3.0 + 1.5 + 2.5] \times 10^{-6} = +\frac{3.5 \times 10^{-6}}{2\varepsilon_0}$$

$$\frac{|E_A|}{|E_B|} = \frac{5.5}{3.5} = 1.57$$

Q10.

A conducting spherical shell with inner radius *a* = 5.0 cm and outer radius *b* = 7.0 cm, has a net charge −3 *Q* on the shell, as shown in **Figure 5**. A positive point charge +*Q* is placed at center of the shell . What is the magnitude of the surface charge density on the outer surface of the shell? Assume Q = 1.5 μC.

Figure 5



A) 4.9×10^{-5} C/m^2
B) 1.7×10^{-5} C/m^2
C) 2.8×10^{-5} C/m^2
D) 3.5×10^{-5} C/m^2
E) 2.1×10^{-5} C/m^2

Ans:

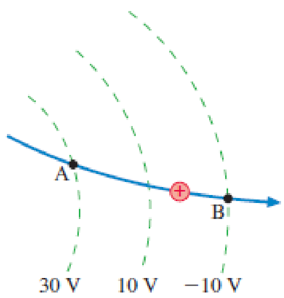
$$q_{outer} = -3Q - (-Q) = -2Q = -2 \times 1.5 \times 10^{-6} C$$

$$|outer\ surface\ charge\ density| = \frac{|q_{outer}\,|}{4\pi R^2} = \frac{3 \times 10^{-6}}{4\pi \times (0.07)^2} = 4.87 \times 10^{-5}\ C/m^2$$

Q11.

A proton's speed as it passes point A is 2.5 × 10^4 m/s. It follows the trajectory AB through the equipotential surfaces shown in **Figure 6**. What is the proton's speed at point B?

Figure 6



A) 9.1×10^4 m/s
B) 1.1×10^4 m/s
C) 2.6×10^4 m/s
D) 3.9×10^4 m/s
E) 5.5×10^4 m/s

Ans:

$$\Delta K = -\Delta U = U_i - U_f = q(V_A - V_B)$$

$$\frac{1}{2} m_p (v_B^2 - v_A^2) = q(V_A - V_B)$$

$$v_B = \sqrt{v_A^2 + \frac{2q}{m_p}(V_A - V_B)}$$

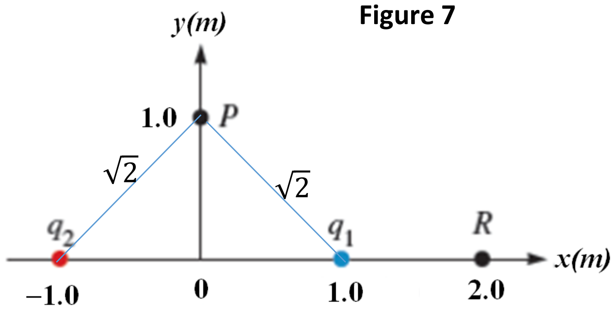
$$= \sqrt{(2.5 \times 10^4)^2 \times \frac{2 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27}}(30 - (-10))}$$

$$v_B = 91047.6\ m/s = 9.1 \times 10^4\ m/s$$

Q12.

Two point charges, q_1 = – 2.0 μC and q_2 = +2.0 μC, are placed on the *x* axis at *x* = 1.0 m and *x* = –1.0 m, respectively, as shown in **Figure 7**. Find the magnitude of the work required to move a third point charge q_3 = +1.0 μC along a straight line from point *P* to point *R*.

Figure 7



A) 12×10^{-3} J
B) 6.6×10^{-3} J
C) 8.1×10^{-3} J
D) 7.7×10^{-3} J
E) 5.5×10^{-3} J

Ans:

$$W = q_3(V_R - V_P)$$

$$V_{P1} = \frac{k}{\sqrt{2}}[q_1 + q_2] = 0$$

$$V_R = k\left(\frac{q_2}{3} + \frac{q_1}{1}\right) = 9 \times 10^9 \left(\frac{2}{3} - 2\right) \times 10^{-6} = -12 \times 10^3 V$$

$$V_R = -12 \times 10^3 V$$

$$|W| = |q_3 V_R| = 1 \times 10^{-6} \times 12 \times 10^{-3} = 12 \times 10^{-3}\ \text{J}$$

Q13.

In a certain region of space, the electric potential is given by *V = 5.0 x^2y – 8.0 xy^2*, where x and y are in meters and V is in Volts. Calculate the magnitude of the electric field at the point in the region that has the coordinates *x* = 2.0 m and *y* = 0.50 m?

A) 8.9 V/m
B) 4.3 V/m
C) 2.0 V/m
D) 3.5 V/m
E) 1.9 V/m

Ans:

$$|E| = \sqrt{E_x^2 + E_y^2}$$

$$E_x = -10xy + 8y^2 = -10 + 2 = -8$$

$$E_y = -5x^2 + 16xy = -20 + 16 = -4$$

$$|E| = \sqrt{(-8)^2 + (-4)^2} = 8.944\ V/m$$

Q14.

Two protons are released from rest when they are 1.00 nm apart. What will be their maximum speed?

A) 1.17×10^4 m/s
B) 2.32×10^4 m/s
C) 1.77×10^4 m/s
D) 3.39×10^4 m/s
E) 4.22×10^4 m/s

Ans:

$$2k_f = U_i = \frac{kq_p^2}{d}$$

$$2 \times \frac{1}{2} \times m_p \times v_f^2 = \frac{kq_p^2}{d}$$

$$v_f = \sqrt{\frac{kq_p^2}{m_p \cdot d}} = \sqrt{\frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{1.67 \times 10^{-27} \times 10^{-9}}} = 1.17 \times 10^4 \text{ m/s}$$

Q15.

A parallel-plate capacitor has plates of area 4.0 cm × 5.0 cm. A 1.0 mm thick dielectric with dielectric constant κ = 3.7 is inserted between the plates. What is the charge that can be stored on this capacitor when connected to a 1.5 V battery?

A) 9.8×10^{-11} C
B) 2.0×10^{-11} C
C) 4.8×10^{-11} C
D) 5.5×10^{-11} C
E) 1.2×10^{-11} C

Ans:

$$Q = C_K \cdot V = \frac{\kappa\varepsilon_0 A}{d} V = \frac{3.7 \times 8.85 \times 10^{-12} \times 20 \times 10^{-14} \times 1.5}{10^3} = 9.8235 \times 10^{-11}\text{C}$$

Q16.

A 1.0 μF capacitor and a 0.50 μF capacitor are connected in series across 100 V potential difference. What is the electrical potential energy stored in the 1.0 μF capacitor?

A) 5.6×10^{-4} J
B) 1.0×10^{-4} J
C) 1.5×10^{-4} J
D) 2.5×10^{-4} J
E) 3.5×10^{-4} J

Ans:

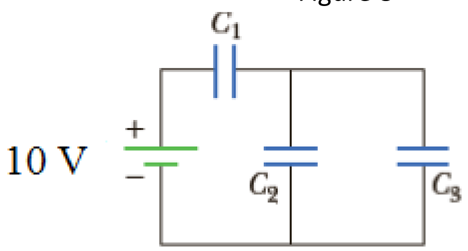
$$U_{1\mu F} = \frac{q_{1\mu F}^2}{2C};\ q_{1\mu F} = q_{0.5\mu F} = c_{eq} \times V = \frac{1 \times 0.5 \times 10^{-6}}{(1 + 0.5)} \times 100 = \frac{10^{-4}}{3} C$$

$$U_{1\mu F} = \frac{\left(\frac{10^{-4}}{3}\right)^2}{2 \times 1 \times 10^{-6}} = 5.555 \times 10^{-4}\ \mathrm{J}$$

Q17.

Three capacitors are connected to a 10 V battery as shown in **Figure 8**. Their capacitances are $C_1 = 3C$, $C_2 = C$, and $C_3 = 5C$. Rank the capacitors according to the magnitude of the charge on each capacitor, **from largest to smallest.**

Figure 8



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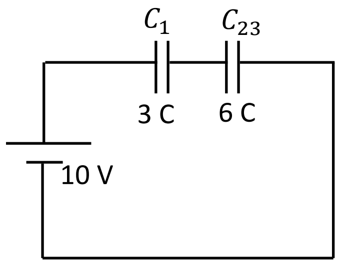

A) C_1, C_3, C_2
B) C_2, C_3, C_1
C) C_3, C_1, C_2
D) C_1, C_2, C_3
E) C_3, C_2, C_1

Ans:

$$C_{123} = \frac{C_1 \times C_{23}}{C_1 + C_{23}} = \frac{3C \times 6C}{3C + 6C} = 2C$$

$$q_{123} = C_{123} \times V = 2C \times 10 = 20\ C$$

$$q_1 = q_{23} = 20\ C$$

$$\Delta V_{23} = \frac{q_{23}}{C_{23}} = 3.33\ V$$

$$q_2 = C_2 \Delta V_{23} = \ C_2 \times 3.33 = 3.33\ C$$

$$q_3 = C_3 \Delta V_{23} = \ 5 \times 3.33 = 16.67\ C$$

$$C_1 < C_2 < C_3$$

Q18.

Two cylindrical resistors R_1 and R_2, made of the same material, have different radii, r_1 and r_2, and different lengths, L_1 and L_2 respectively. Which of the following relationship between radii and lengths would result in equal resistances?

A) $2r_1 = r_2$ and $4L_1 = L_2$
B) $r_1 = r_2$ and $L_1 = 2L_2$
C) $2r_1 = r_2$ and $L_1 = 2L_2$
D) $r_1 = r_2$ and $4L_1 = L_2$
E) $r_1 = r_2$ and $3L_1 = L_2$

Ans:

$$R = \rho \frac{l_1}{\pi r_1^2} = \rho \frac{l_2}{\pi r_2^2}$$

$$\frac{l_2}{l_1} = \frac{r_2^2}{r_1^2} = \left(\frac{r_2}{r_1}\right)^2$$

$$l_2 = 4l_1$$

$$r_2 = 2r_1$$

Q19.

A 100 W light bulb is to be operated at 120 V line. If the line voltage changes to 140 V, what is the magnitude of the change in the light bulb power, assuming that the bulb electrical resistance remains constant?

A) 36 W
B) 20 W
C) 11 W
D) 47 W
E) 30 W

Ans:

For constant resistance R

$$\frac{P_2}{P_1} = \left(\frac{V_2}{V_1}\right)^2 ;\ P_2 = P_1 \times \left(\frac{V_2}{V_1}\right)^2 = 100 \times \left(\frac{140}{120}\right)^2 = 136.11 \text{ W}$$

$$\Delta P = P_2 - P_1 = 136.11 - 100 = 36.11 \text{ W}$$

Q20.

Uniform wire W_1 with 1.0 m in length and 1.0 mm in diameter is connected to one end of another uniform wire W_2 of the same material with 2.0 m in length and 2.0 mm in diameter. A voltage source is connected across the wires and a current is passed through them. If it takes an average time of τ s for a conduction electron to travel through wire W_1, how long does it take for such an electron to travel through wire W_2?

A) 8τ
B) 4τ
C) 2τ
D) τ/4
E) τ/8

Ans:

$$v_d \propto J \Rightarrow v_d \propto \frac{1}{A}\ (for\ constant\ I)$$

$$v_{d2} = v_{d1} \times \frac{\pi r_2^2}{\pi r_1^2} = v_{d1} \times \frac{r_2^2}{r_1^2}$$

$$For\ wire\ W_1;\ \ \tau_{w1} = \frac{lw_1}{v_{d1}}, \tau_{w2} = \frac{lw_2}{vd_2}$$

$$\tau_{w2} = \tau_{w1} \times \frac{lw_2}{lw_1} \times \frac{v_{d2}}{v_{d1}}$$

$$\tau_{w2} = \tau \times 2 \times \left(\frac{r_2}{r_1}\right)^2 = \tau \times 2 \times \left(\frac{1.0}{0.5}\right)^2 = 8\tau$$