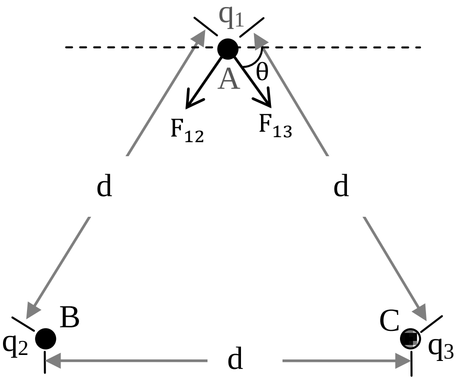
Q1.

Three charges (q_1 = + 6.0 μC, q_2 = – 4.0 μC, q_3 = – 4.0 μC) are fixed at the corners of an equilateral triangle of side *d* = 3.0 m as shown in **FIGURE 1**. What is the magnitude of the force acting on charge q_1?

Figure 1



A) 0.042 N
B) 0.058 N
C) 0.14 N
D) 0.034 N
E) 0.072 N

Ans:

The forces on q_1 are shown

$F_{12} = F_{13}$ in magnitude.
They also make the same angle θ

$\Rightarrow$ Their x – components cancel
Their y – components add up

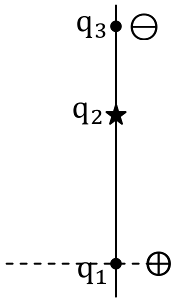
$$F_{1,net} = 2.F_{12}.\sin\theta$$

$$= 2 \times \frac{kq_1q_2}{d^2}.\sin 60^\circ$$

$$= \frac{2 \times 9 \times 10^9 \times 6 \times 4 \times 10^{-12}}{9} \times \sin 60^\circ = 0.042\ \text{N}$$

Q2.

Consider the following three point charges that are fixed on the *y*-axis: q_1 = + 2.00 μC located at y_1 = 0, q_2 located at y_2 = 6.00 m, and q_3 = – 1.00 μC located at y_3 = 8.00 m. What is the value of q_2 such that q_3 is in equilibrium?



A) – 0.125 μC
B) + 0.125 μC
C) – 1.13 μC
D) + 1.13 μC
E) + 1.00 μC

Ans:

For q_3 to be in equilibrium: q_2 must be (-)

$$F_{31} = F_{32}: \frac{\cancel{k}q_1\cancel{q_3}}{64} = \frac{\cancel{k}q_2\cancel{q_3}}{4} \Rightarrow q_2 = \frac{4}{64}q_1$$

$$\Rightarrow q_2 = \frac{4}{64} \times 2 = 0.125\mu C$$

$$\therefore q_2 = -0.125\mu C$$

Q3.

An electric dipole is placed in an external uniform electric field. When the electric dipole rotates until its dipole moment is aligned with the field:

A) the electric field does positive work and the potential energy decreases.✓
B) the electric field does positive work and the potential energy increases.✗
C) the electric field does negative work and the potential energy increases. ✗
D) the electric field does negative work and the potential energy decreases. ✗
E) the electric field does no work. ✗

Ans:

$$U = -\vec{p}.\vec{E}$$

$$U(\text{parallel}) = -pE$$

$$\Rightarrow \ \Delta U < 0$$

$$\Rightarrow \ W > 0$$

Q4.

A uniform electric field has a magnitude of 2.0 × 10^4 N/C and points to the right. An electron is released from rest in this electric field. How far and in what direction will the electron travel in two nanoseconds after its release?

A) 7.0 mm to the left
B) 7.0 mm to the right
C) 14 mm to the left
D) 3.5 mm to the left
E) 3.5 mm to the right

Ans:

$$\rightarrow \vec{E}$$

$$\leftarrow \vec{a}$$

$$x = \overset{0}{\cancel{v_i}} t + \frac{1}{2}\, at^2$$

$$= \left(\frac{1}{2}\right)\left(\frac{eE}{m}\right) t^2$$

$$= \frac{1.6 \times 10^{-19} \times 2 \times 10^4 \times 4 \times 10^{-18}}{2 \times 9.11 \times 10^{-31}}$$

$$= 0.70 \times 10^{-2} = 7.0\ \text{mm}$$

Q5.

Electric charge is uniformly distributed throughout the volume of a solid insulating sphere. Let ***r*** be the distance from the center of the sphere. Which of the following quantities varies as $\boldsymbol{r^2}$ inside the sphere?

A) The electric potential
B) The electric field
C) The electric charge
D) The electric flux
E) The product of charge and flux

Ans:

$$E = \frac{kq}{R^3}\,r$$

$$V = \int E dr = \frac{kq}{2R^3}\,r^2 + \text{constant}$$

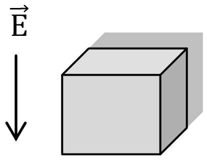
$$q = \rho.V = (\rho)\left(\frac{4\pi}{3}r^3\right) = \frac{4\pi\rho}{3}r^3$$

$\Phi \rightarrow$ same as q

Q6.

The electric field in a certain region of the Earth's atmosphere is directed vertically downward. At an altitude of 150 m, the field has a magnitude of 30 N/C. At an altitude of 100 m, the magnitude of the electric field is 50 N/C. Find the net amount of electric charge contained in a cube 50 m on edge, with horizontal faces at altitudes of 100 and 150 m.

A) 0.44 μC
B) 1.8 μC
C) 2.1 μC
D) 1.3 μC
E) 4.4 μC



Ans:

$$\Phi = \vec{E}.\vec{A}$$

Electric flux will be only through the top and lower faces.

The area of a face: $A = 50 \times 50 = 2500\ \text{m}^2$

Top : $\Phi_t = -EA = -30 \times 2500 = -75000\ \text{N.m}^2/\text{C}$

Bottom : $\Phi_b = +EA = +50 \times 2500 = +125000\ \text{N.m}^2/\text{C}$

$$\Phi_{net} = \Phi_t + \Phi_b = +50000\ \text{N.m}^2/\text{C}$$

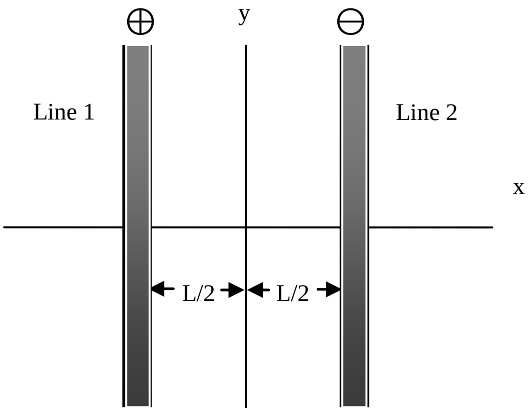
$$\Phi_{net} = \frac{q_{enc}}{\varepsilon_0} \Rightarrow q_{enc} = \varepsilon_0.\Phi_{net} = 8.85 \times 10^{-12} \times 5 \times 10^4$$

$$= 4.4 \times 10^{-7}\ \text{C} = 0.44\ \mu\text{C}$$

Q7.

In **FIGURE 2**, short sections of two very long parallel lines of charge are shown, fixed in place, and separated by *L* = 10 cm. Their uniform linear charge densities are + 8.0 mC/m for line 1, and – 4.0 mC/m for line 2. What is the *x* coordinate of the point at which the net electric field due to the two lines is zero.

Figure 2



A) 15 cm
B) 5.0 cm
C) 20 cm
D) 25 cm
E) 10 cm

Ans:

The electric field cannot be zero between the lines.

⇒ The requested point has to be to right of 2 or to the left of 1, closer to the weaker

Since $|\lambda_2| < |\lambda_1| \Rightarrow$ The point has to be to the right of line 2, a distance d from it.

$$E_1 = E_2 : \frac{\cancel{2k}\lambda_1}{L+d} = \frac{\cancel{2k}\lambda_2}{d} \Rightarrow \frac{L+d}{d} = \frac{\lambda_1}{\lambda_2} \Rightarrow \frac{L}{d} + 1 = \frac{8}{4} = 2$$

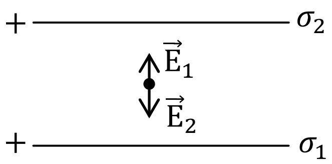
$$\Rightarrow \frac{L}{d} = 1 \Rightarrow d = L$$

$$\Rightarrow x = \frac{L}{2} + L = \frac{3L}{2} = 15\text{ cm}$$

Q8.

Two large, parallel, non-conducting uniformly charged sheets carry surface charge densities of + 12.0 nC/m^2 and + 5.00 nC/m^2. Determine the magnitude of the electric field at a point midway between the sheets.

A) 395 N/C
B) 960 N/C
C) 790 N/C
D) 1920 N/C
E) 565 N/C



Ans:

$$E_1 = \frac{\sigma_1}{2\epsilon_0};\ E_2 = \frac{\sigma_2}{2\epsilon_0}$$

$$E_{net} = E_1 - E_2 = \frac{\sigma_1 - \sigma_2}{2\epsilon_0}$$

$$= \frac{(12-5)\times 10^{-9}}{2\times 8.85\times 10^{-12}} = 395\text{ N/C}$$

Q9.

A square, with an edge length of 1.3 m, has four point charges fixed at its corners as follows: q_1 = + 12 nC, q_2 = – 24 nC, q_3 = + 31 nC, and q_4 = + 17 nC. Calculate the electric potential at the centre of the square due to the four point charges.

A) 3.5×10^2 V
B) 3.5×10^3 V
C) 4.5×10^2 V
D) 5.5×10^2 V
E) 4.5×10^3 V

Ans:

r = distance from corner to center

d = edge length

$(2r)^2 = d^2 + d^2 \Rightarrow r = \frac{d}{\sqrt{2}} \rightarrow$ same for all charges

$$V_c = \sum_{i=1}^{4} \frac{kq_i}{r_i} = \frac{k}{r} \sum_{i=1}^{4} q_i$$

$$= \frac{9 \times 10^9 \times \sqrt{2}}{1.3} \times (12 - 24 + 31 + 17) \times 10^{-9} = 3.5 \times 10^2 \text{ V}$$

Q10.

Two large, parallel, metal plates are 1.48 cm apart and carry equal but opposite charges on their facing surfaces. The electric potential on the negative plate is zero. If the potential halfway between the plates is + 5.52 V, what is the magnitude of the electric field in this region?

A) 746 V/m
B) 349 V/m
C) 562 V/m
D) 426 V/m
E) 339 V/m

Ans:

$$E = \frac{\Delta V}{\Delta x} = \frac{\Delta V}{(d/2)} = \frac{2 \times \Delta V}{d} = \frac{2 \times 5.52}{0.0148} = 746 \text{ V/m}$$

Q11.

Two conducting spheres, one of radius 6.0 cm and the other of radius 12 cm, each has a charge of 30 nC and are very far apart. If the spheres are subsequently connected by a conducting wire, find the electric potential on each sphere, assuming *V* = 0 at infinity.

A) 3.0 kV
B) 2.6 kV
C) 2.4 kV
D) 2.2 kV
E) 2.8 kV

Ans:

$$Q_i = 2 \times 30 = 60\ \mathrm{nC}$$

$$\left.\begin{aligned} V_{1f} &= \frac{kq_{1f}}{R_1} \\ V_{2f} &= \frac{kq_{2f}}{R_2} \end{aligned}\right\} \text{since } V_{1f} = V_{2f} : \frac{\cancel{k}q_{1f}}{R_1} = \frac{\cancel{k}q_{2f}}{R_2} \Rightarrow \frac{q_{2f}}{q_{1f}} = \frac{R_2}{R_1} = \frac{12}{6} = 2$$

$$Q_f = q_{1f} + q_{2f} = q_{1f} + 2q_{1f} = 3q_{1f}$$

$$\text{But } Q_i = Q_f : \quad Q_i = 3q_{1f} \Rightarrow q_{1f} = \frac{Q_i}{3} = 20\ \mathrm{nc}$$

$$\Rightarrow V_{1f} = \frac{9 \times 10^9 \times 20 \times 10^{-9}}{0.06} = 3000\ \mathrm{V}$$

Q12.

A charged particle is released in a uniform external electric field. Which of the following statements is CORRECT?

A) The electric potential energy of the particle always decreases. ✓ $\Delta U = q.\Delta V$
B) The electric potential energy of the particle always increases. ✗
C) The electric potential energy of the particle does not change. ✗
D) The electric potential energy increases if the particle has positive charge. ✗
E) The electric potential energy increases if the particle has negative charge. ✗

Ans:

A

Q13.

Two identical charged particles (*m* = 1.00 g, *q* = 15.0 μC) are initially held 1.00 cm away from each other. They are released from rest. What is the speed of each particle when the distance between them is doubled?

A) 318 m/s
B) 159 m/s
C) 225 m/s
D) 176 m/s
E) 217 m/s

Ans:

Let r = initial separation

$$\cancelto{0}{K_i} + U_i = K_f + U_f$$

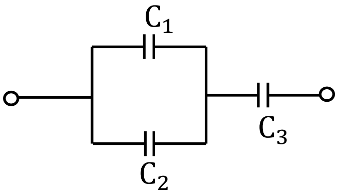
$$K_f = U_i - U_f = \frac{kq^2}{r} - \frac{kq^2}{2r} = \frac{kq^2}{2r}$$

$$2 \times \frac{1}{2} mv^2 = \frac{kq^2}{2r} \Rightarrow v = \sqrt{\frac{kq^2}{2mr}} = 318\ \text{m/s}$$

Q14.

Find the equivalent capacitance of the combination of two parallel capacitors C_1 and C_2 that are connected in series with capacitor C_3, where C_1 = 12 μF, C_2 = 5.0 μF, and C_3 = 4.0 μF.

A) 3.2 μF
B) 4.3 μF
C) 7.0 μF
D) 5.3 μF
E) 1.4 μF



Ans:

$$C_{12} = C_1 + C_2 = 17\ \mu\text{F}$$

$$C_{eq} = \frac{C_{12} . C_3}{C_{12} + C_3} = \frac{17 \times 4}{17 + 4} = 3.2 \mu\text{F}$$

Q15.

A 3.6 μF capacitor, C_1, is charged to a potential difference of 6.3 V, using a battery. The charging battery is then removed, and the capacitor is connected in parallel to an un-charged 9.0 μF capacitor, C_2. What is the final common potential difference across the two capacitors?

A) 1.8 V
B) 2.4 V
C) 4.4 V
D) 2.2 V
E) 2.6 V

Ans:

$$Q_i = C_1 . V_i = 3.6 \times 6.3 = 22.68\ \mu C$$

$$\left.\begin{matrix} q_{1f} = C_1 . V_f \\ q_{2f} = C_2 . V_f \end{matrix}\right\} Q_f = q_{1f} + q_{2f} = (C_1 + C_2)V_f = 12.6\ V_f$$

But $Q_i = Q_f$: $22.68 = 12.6\ V_f \Rightarrow V_f = 1.8\ V$

Q16.

An air-filled parallel-plate capacitor, whose capacitance is 13.5 pF, is charged using a battery to a potential difference of 12.5 V across its plates. The charging battery is now disconnected and a dielectric slab (κ = 6.50) is inserted between the plates. What is the stored energy in the capacitor after the slab is inserted?

A) 162 pJ
B) 154 nJ
C) 222 nJ
D) 476 pJ
E) 111 pJ

Ans:

$$C_f = \kappa C_i = 6.5 \times 13.5 = 87.75\ pF$$

Charge is conserved: $Q = C_i V_i = 13.5 \times 12.5 = 168.75\ pC$

$$U_f = \frac{Q^2}{2C_f} = \frac{(168.75 \times 10^{-12})^2}{2 \times 87.75 \times 10^{-12}} = 1.62 \times 10^{-10}\ J = 162 \times 10^{-12}\ J = 162\ pJ$$

Q17.

A parallel plate capacitor is connected to a battery that maintains a constant electric potential difference between the plates. If the plates of the capacitor are pulled further apart

A) The magnitude the electric field between the plates will decrease.✓
B) The capacitance of the capacitor will increase.✗
C) The charge on each plate will not change. ✗
D) The energy stored in the capacitor will increase. ✗
E) The energy stored in the capacitor will not change. ✗

Ans:

$$E = \frac{V}{d}\,; C = \frac{\varepsilon_0}{d}A; Q = CV$$

$$U = \frac{1}{2}CV^2$$

Q18.

A 120 V potential difference is applied to the ends of a conducting wire, causing a current of 16 A to pass through it. If the length of the wire is 1.0 m, and the resistivity of its material is 1.0×10^{-6} Ω.m, what is the radius of the wire?

A) 0.21 mm
B) 0.32 mm
C) 0.47 mm
D) 0.13 mm
E) 0.65 mm

Ans:

$$R = \frac{V}{i} = \frac{120}{16} = 7.5\Omega$$

$$R = \frac{\rho L}{A} = \frac{\rho L}{\pi r^2}$$

$$\Rightarrow r^2 = \frac{\rho L}{\pi R} \Rightarrow r = \sqrt{\frac{\rho L}{\pi R}} = \left[\frac{1.0 \times 10^{-6} \times 1.0}{\pi \times 7.5}\right]^{\frac{1}{2}} = 2.06 \times 10^{-4}\ \mathrm{m} = 0.21\ \mathrm{mm}$$

Q19.

A light bulb has a 120 V potential difference applied to it. If the potential difference is increased to 150 V, what is the fractional increase in the power dissipated in the light bulb? Assume that the resistance of the light bulb remains constant.

A) 0.56
B) 0.25
C) 0.20
D) 0.36
E) 0.64

Ans:

$$\left.\begin{aligned} P_i &= \frac{V_i^2}{R} \\ P_f &= \frac{V_f^2}{R} \end{aligned}\right\} \text{fractional change} = f = \frac{\Delta P}{P_i} = \frac{P_f - P_i}{P_i} = \frac{P_f}{P_i} - 1$$

$$= \left(\frac{V_f}{V_i}\right)^2 - 1 = \left(\frac{150}{120}\right)^2 - 1 = 0.56$$

Q20.

The filament of a light bulb is initially at 20.0 °C. It is connected to a voltage source which maintains a constant potential difference across the filament. The current in the bulb when it reaches its final operational temperature is one-tenth its value when the bulb is first turned on. What is the final operational temperature of the filament? Assume that the dimensions of the filament do not change, and that the temperature coefficient of resistivity of the filament is 0.00450 $(^{\circ}\mathrm{C})^{-1}$.

A) 2020 °C
B) 2000 °C
C) 1980 °C
D) 2040 °C
E) 1960 °C

Ans:

$$I_f = \frac{I_0}{10} \Rightarrow \frac{V}{R_f} = \frac{V}{10R_0} \Longrightarrow R_f = 10R_0$$

$$\downarrow$$

$$\cancel{R_0}(1 + \alpha\Delta T) = 10\cancel{R_0}$$

$$1 + \alpha\Delta T = 10$$

$$\alpha\Delta T = 9$$

$$\Rightarrow \Delta T = \frac{9}{\alpha} = \frac{9}{0.0045} = 2000\ ^{\circ}\mathrm{C}$$

$$T_f = T_0 + \Delta T = 2020\ ^{\circ}\mathrm{C}$$
