Q1.

Particles A and B are electrically neutral and are separated by 5.0 μm. If 5.0×10^6 electrons are transferred from particle A to particle B, the magnitude of the electric force between them is:

A) 2.3×10^{-4} N
B) 1.3×10^{-4} N
C) 1.0×10^{-4} N
D) 1.0×10^{-3} N
E) 5.0×10^{-3} N

Solution:

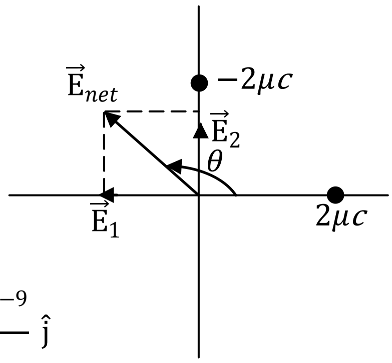
$$F = \frac{kq^2}{r^2} = -\frac{9\times 10^9 \times (5\times 10^6 \times 1.6\times 10^{-19})}{(5\times 10^{-6})^2} = 2.3 \times 10^{-4}\ \text{N}$$

Sec# Electric Charge - Coulomb's Law

Q2.

Two charges, +2.00 nC and –2.00 nC, are positioned at the coordinates (1.00 m , 0) and (0, 1.00 m) respectively in an isolated space. The magnitude and direction of the electric field at the origin are:

A) 25.5 N/C, 135^0 from positive x-axis
B) 25.5 N/C , 225^0 from positive x-axis
C) 36.0 N/C, 135^0 from positive x-axis
D) 18.0 N/C, 45^0 from positive x-axis
E) 5.25 N/C, 225^0 from positive x-axis



Solution:

$$\vec{E} = -\frac{9\times 10^9 \times 2\times 10^{-6}}{1^2}\hat{\imath} + \frac{9\times 10^9 \times 2\times 10^{-9}}{1^2}\hat{j}$$

$$= -18\hat{\imath} + 18\hat{j}$$

$$|\vec{E}| = \sqrt{18^2 + 18^2} = 25.5\ \text{N}/C$$

$$\theta = \tan^{-1}\left(-\frac{18}{18}\right) = -45° = 135° \text{ from positive x-axis}$$

Sec# Electric fields - The Electric Field Due to a Point Charge

---

Q3.

An electric dipole moment of magnitude $p = 3.02 \times 10^{-25}$ C.m makes an angle 64^o with a uniform electric field of magnitude E = 46.0 N/C. The work required to turn the electric dipole by 90^o is:

A) 1.86×10^{-23} J
B) 3.00×10^{-23} J
C) 2.22×10^{-23} J
D) 1.86×10^{-22} J
E) 2.22×10^{-22} J

Solution:

$$W_a = \Delta u = u_f - u_i = -E_p \cos 154° - (-E_p \cos 64°)$$

$$= E_p (\cos 64° - \cos 154°) = 46 \times 3.02 \times 10^{-25} (0.438 + 0.898)$$

$$= 1.86 \times 10^{-23} \text{ J}$$

Sec# Electric fields - A Dipole in an Electric Field

Q4.

What is **NOT TRUE** about electric field lines:

A) They are extended away from a negative point charge.
B) They are the path followed by a unit positive charge.
C) Two electric field lines never cross each other.
D) They are imaginary lines used to visualize the patterns in the electric field.
E) The direction of the electric field at a point in the field line is given by the tangent at that point.

Ans.

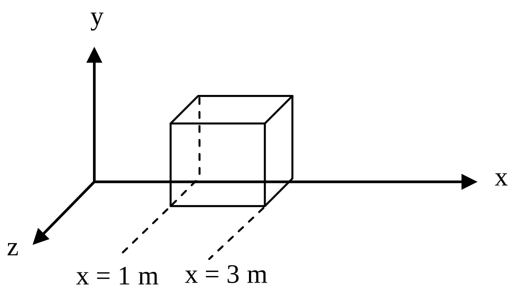
A and **B**.

Sec# Electric fields - Electric Field Lines

Q5.

Figure 1 shows a Gaussian cube in region where the electric field $\vec{E}$ is along the y-axis. $\vec{E} = -30.0\ \hat{j}$ N/C on the top face and $+20.0\ \hat{j}$ N/C on the bottom face of the cube. Determine the net charge contained within the cube.

Fig# 1



A) -1.77×10^{-9} C
B) $+1.77 \times 10^{-9}$ C
C) -3.98×10^{-9} C
D) $+3.98 \times 10^{-9}$ C
E) -3.54×10^{-10}C

Solution:

$$\emptyset = \vec{E} \cdot \vec{A} = \frac{q_{end}}{\varepsilon_0}$$

$$= -30 \times 4 - 20 \times 4 = \frac{q_{end}}{\varepsilon_0}$$

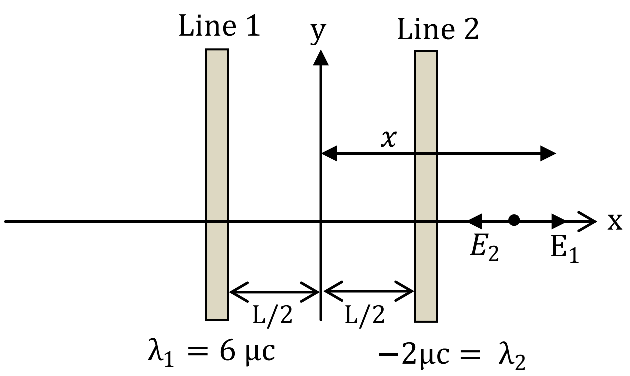
$$\Longrightarrow q_{end} = -200 \times 8.85 \times 10^{-12} = -1.77 \times 10^{-12} \text{ C}$$

Sec# Gauss's law - Gauss's Law

Q6.

Figure 2 shows short sections of two very long parallel lines of charge, fixed in place and separated by L = 10 cm. The uniform linear charge densities are +6.0 μC/m for Line 1 and –2.0 μC/m for Line 2. Find the x-coordinate of the point along the x-axis at which the net electric field due to the two line charges is zero.

Fig #2



A) +10 cm
B) –10 cm
C) –15 cm
D) +15 cm
E) Zero

Solution:

$$E_2 = E_1 \Longrightarrow \frac{2k|\lambda_1|}{r_1} = \frac{2k|\lambda_2|}{r_2}$$

$$\frac{|\lambda_1|}{\frac{L}{2}+x} = \frac{|\lambda_2|}{x-\frac{L}{2}} \Rightarrow 6\left(x-\frac{L}{2}\right) = 2\left(\frac{L}{2}+x\right)$$

$\Rightarrow 4L = 4x \quad \Rightarrow x = L = 10$ cm

Sec# Gauss's law - Applying Gauss's Law: Cylindrical Symmetry

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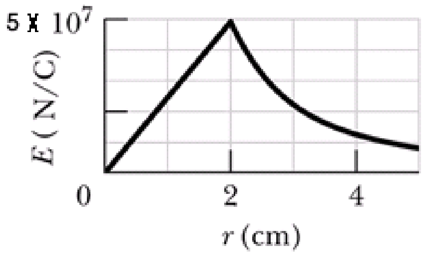
Q7.

Figure 3 shows the magnitude of the electric field due to a sphere with a positive charge distributed uniformly throughout its volume. What is the value of the charge on the sphere?

Fig# 3



A) 2 μC
B) 1 μC
C) 3 μC
D) 4 μC
E) 5 μC

Solution:

$$E = \frac{kQ}{R^2}$$

$$5 \times 10^7 = \frac{9 \times 10^9 \times Q}{(0.02)^2}$$

$$\Rightarrow Q = 2.2 \times 10^{-6}\text{ C}$$

Sec# Gauss's law - Applying Gauss's Law: Spherical Symmetry

Q8.

Which of the following statements is **NOT TRUE**?

A) If a charged particle is placed inside a spherical shell of uniform charge density, there is a non-zero electrostatic force on the particle from the shell.
B) The electric field is zero everywhere inside a conductor in electrostatic equilibrium.

C) Any excess charge placed on an isolated conductor in electrostatic equilibrium resides on its surface.
D) The electric field just outside a charged conductor in electrostatic equilibrium is perpendicular to its surface.
E) The net electric flux through any closed surface is proportional to the net charge inside the surface.

Ans.

A.

Sec# Gauss's law - A Charged Isolated Conductor

Q9.

An electron is released from rest in a downward electric field of magnitude 1500 N/C. Determine the change in electric potential energy of the electron when it has moved a vertical distance of 20 m in this electric field.

A) -4.8×10^{-15} J
B) $+4.8 \times 10^{-15}$ J
C) -2.4×10^{-15} J
D) $+2.4 \times 10^{-15}$ J
E) $+1.2 \times 10^{-15}$ J

Solution:

$\Delta U = 9\Delta V = 9\,(-\mathrm{E}d\ \cos 180°)$

$= 9\ \mathrm{E}\,d = (-1.6 \times 10^{-19}) \times 1500 \times 20$

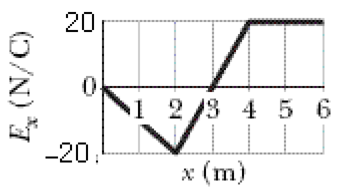
$= -4.8 \times 10^{-15}$ J

Sec# Electric Potential - Electric Potential Energy

Q10.

Figure 4 shows the x component of the electric field as a function of x in a region. The y and z components of the electric field are zero in this region. If the electric potential at x = 0 is 10 V, what is the electric potential at x = 3 m?

Fig. # 4



A) +40 V

B) +30 V
C) –30 V
D) –40 V
E) –10 V

Solution:

$$\Delta V = -\int \vec{E} \cdot d\vec{s} = -\int_0^3 E_x \, dx$$

$$= -\text{Area under the curve}$$

$$\Delta V = -\left[\frac{1}{2} \times 3 \times (-20)\right] = 30 \text{ V}$$

$$V_f = 30 \text{ V} + V_i = 40 \text{ V}$$

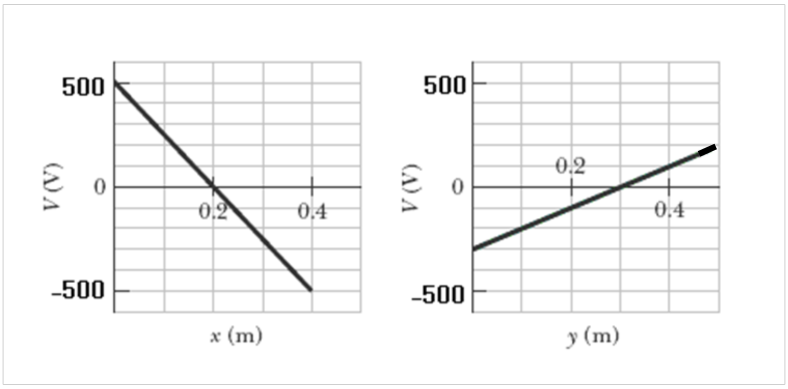
Sec# Electric Potential - Calculating the Potential from the Field

---

Q11.

A particle of charge 2×10^{-3} C is placed in an xy plane where the electric potential depends on x and y as shown in Figure 5. The potential does not depend on z. What is the electric force (in N) on the particle?

Fig# 5



A) $+5\hat{i} - 2\hat{j}$
B) $-5\hat{i} + 2\hat{j}$
C) $+2\hat{i} - 5\hat{j}$
D) $-2\hat{i} + 5\hat{j}$
E) $+5\hat{i} + 2\hat{j}$

Solution:

$$\vec{F} = 9\,\vec{E} = 9\left(-\frac{\Delta V_x}{\Delta x}\hat{\imath} - \frac{\Delta V_y}{\Delta Y}\hat{\jmath}\right)$$

$$= 2\times 10^{-3}\left[-\frac{-1000}{0.4}\hat{\imath} - \frac{500}{0.5}\hat{\jmath}\right]$$

$$= 5\,\hat{\imath} - 2\hat{\jmath}\ N$$

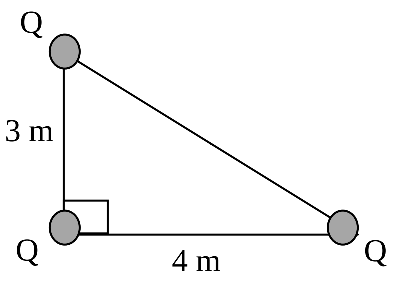
Sec# Electric Potential - calculating the Field from the Potential

---

Q12.

How much work is required to set up the arrangement of charges shown in Figure 6, if Q = – 3 μC? Assume that the charged particles are initially infinitely far apart and at rest. Take the potential to be zero at infinity.

Fig # 6



A) +0.06 J
B) –0.06 J
C) +0.03 J
D) –0.03 J
E) –0.02 J

Solution:

$$W_a = \Delta u = u_f - \cancel{u_i}$$

$$= kQ^2\left(\frac{1}{r_{12}} + \frac{1}{r_{13}} + \frac{1}{r_{23}}\right)$$

$$= 9\times 10^{9}\times(-3\times 10^{-6})^2\left(\frac{1}{5}+\frac{1}{3}+\frac{1}{4}\right) = 0.06\ \text{J}$$

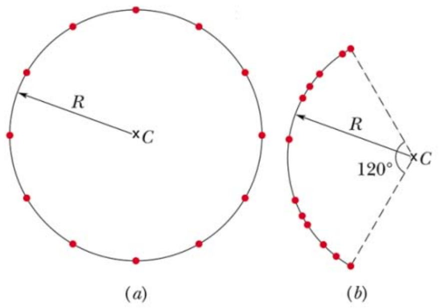
Sec# Electric Potential - Electric Potential Energy of a System of Point Charges

---

Q13.

Figure 7 shows two different arrangements of 12 electrons fixed in space. In the arrangement (a) they are uniformly spaced around a circle of radius R and in (b) they are non-uniformly spaced along an arc of the original circle. Which of the following statements is **TRUE**?

Fig# 7



A) The electric potential at the center C is the same in both (a) and (b).
B) The electric potential at the center C is larger in (b) than that in (a).
C) The magnitude of electric field at the center C is the same in both (a) and (b).
D) The magnitude of electric field at the center C is smaller in (b) than that in (a).
E) The electric potential and the electric field at the center C are both zero in (a).

Ans.

A

Sec# Electric Potential - Potential Due to a Group of Point Charges

---

Q14.

A parallel-plate capacitor has a plate area of 0.20 m^2 and a plate separation of 0.10 mm. To obtain an electric field of 2.0 x 10^6 N/C between the plates, the magnitude of the charge on each plate should be:

A) 3.5 x 10^{-6} C
B) 1.8 x 10^{-6} C
C) 7.1 x 10^{-6} C
D) 8.9 x 10^{-6} C
E) 1.4 x 10^{-6} C

Solution:

$$Q = CV = \frac{\varepsilon_0 A}{\not{d}} E\not{d}$$

$$= 8.85 \times 10^{-12} \times 0.2 \times 2 \times 10^{6}$$

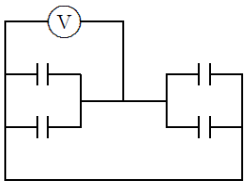
$= 3.54 \times 10^{-6}$ C

Sec# Capacitance - Calculating the Capacitance

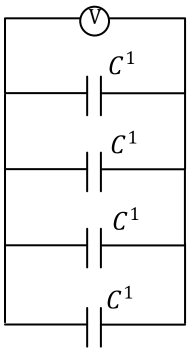
Q15.

Figure 8 shows an arrangement of four capacitors, 500 μF each with air between the plates. When the space between the plates of each capacitor is filled with a material of dielectric constant 2.50, the voltmeter reads 1000 V. The magnitude of the charge, in Coulombs, on each capacitor plate is:

Fig#8



A) 1.25
B) 0.250
C) 20.5
D) 52.5
E) 100



Solution:

$C^1 = \text{kc} = 2.5 \times 500 \times 10^{-6} = 1.25 \times 10^{-3}$ F

$Q^1 = C^1 V = 1.25 \times 10^{-3} \times 10^3 = 1.25$ C

Sec# Capacitance - Capacitors in Parallel and in Series

Q16.

Two parallel-plate capacitors with the same capacitance but different plate separation are connected in series to a battery. Both capacitors are filled with air. The quantity that is **NOT** the same for both capacitors when they are fully charged is:

A) The electric field between the plates
B) The stored energy
C) The potential difference
D) The charge on the positive plate
E) The dielectric constant

Ans.

A.

Sec# Capacitance - Capacitors in Parallel and in Series

Q17.

An air filled parallel-plate capacitor has a capacitance of 3.0 pF. The plate separation is then increased three times and a dielectric material is inserted, completely filling the space between the plates. As a result, the capacitance becomes 5.0 pF. The dielectric constant of the material is:

A) 5.0
B) 10
C) 2.0
D) 4.0
E) 3.0

Solution:

$$C_0 = 3\text{pF}$$

$$C_0 = \frac{\varepsilon_{0A}}{d}$$

$$C_1 = \frac{\varepsilon_{0A}}{3d} = \frac{C_0}{3} = 1\text{pF}$$

$$C_2 = kG = 5 \times 1\text{pF} = 5\text{pF}$$

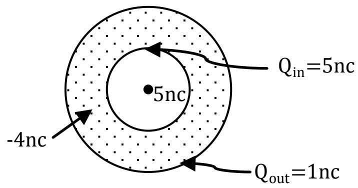
Sec# Capacitance - Capacitor with a Dielectric

Q18.

A hallow spherical conductor of inner radius 2.0 cm and outer radius 4.0 cm has a net charge of – 4.0 nC. If a point charge of 5.0 nC is placed at the center of the hallow spherical conductor, the charge density on the outer surface of the conductor is:

A) + 50 nC/m^2
B) + 80 nC/m^2
C) – 50 nC/m^2
D) – 80 nC/m^2
E) + 40 nC/m^2

Solution:



$$\sigma_{out} = \frac{Q_{out}}{A} = \frac{1 \times 10^{-9}}{4\pi(0.04)^2}$$

$$\sigma_{out} = 49.7 \times 10^{-9}\ \text{C} \approx 50\ \text{nc}$$

Sec# Gauss's law - Applying Gauss's Law: Spherical Symmetry

Q19.

Two small charged objects attract each other with a force F when separated by a distance d. If the charge on each object is reduced to one-fourth of its original value and the distance between them is reduced to d/2 the force becomes:

A) F/4
B) F/2
C) F/16
D) F
E) F/8

Solution:

$$F = \frac{kq_1q_2}{d^2}$$

$$F' = \frac{k\,\frac{q_1}{4}\,\frac{q_2}{4}}{\left(\frac{d}{2}\right)^2} = \frac{k\,q_1\,q_2}{16\,\frac{d^2}{4}} = \frac{k\,q_1\,q_2}{4d^2} = \frac{F}{4}$$

Sec# Electric Charge - Coulomb's Law

Q20.

Eight identical spherical raindrops are each at a potential V (assuming the potential to be zero at infinity). They combine to make one spherical raindrop whose potential is:

A) 4V
B) 2V
C) V/2
D) V/4
E) V/8

Solution:

Volume 2 = 8 volume 1

$$\frac{4}{3}\pi {R_2}^3 = 8\,\frac{4}{3}\pi {R_1}^3 \Rightarrow R_2 = 2R_1$$

$$V_2 = \frac{k\cdot 8Q}{R_2} = \frac{k\cdot 8Q}{2R_1} = \frac{4kQ}{R_1} = 4\text{ V}$$

Sec# Electric Potential - Potential Due to a Group of Point Charges

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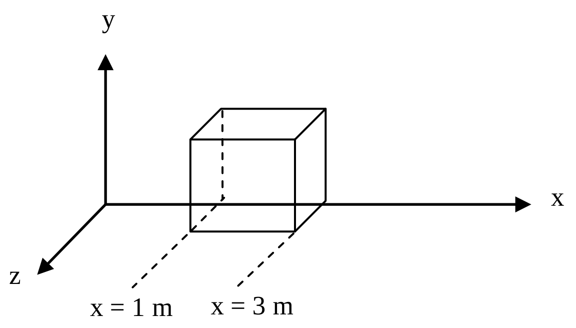

Figure 1

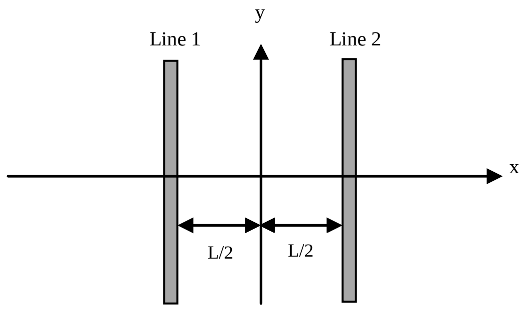

Figure 2

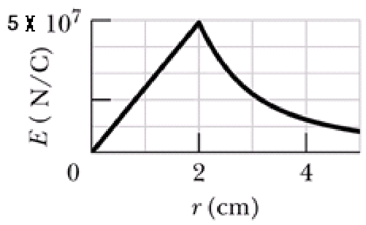

Figure 3

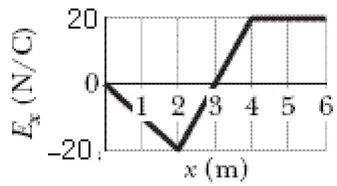

Figure 4

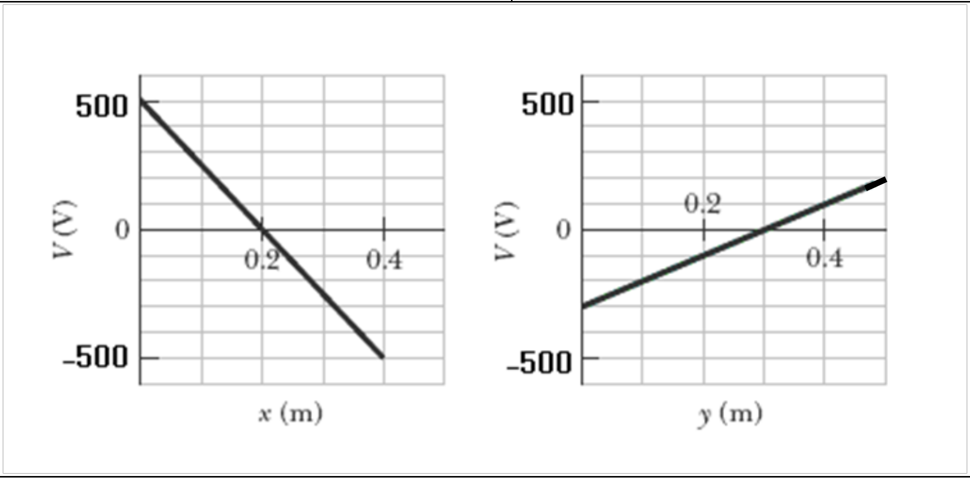

Figure 5

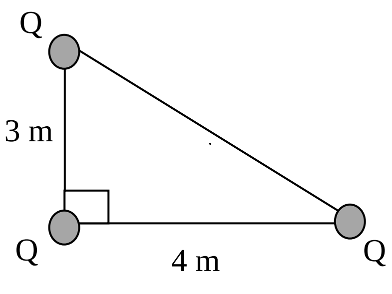

Figure 6

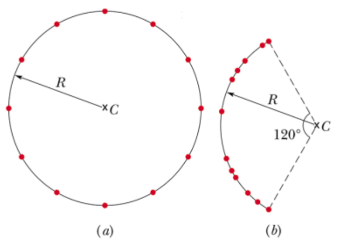

Figure 7

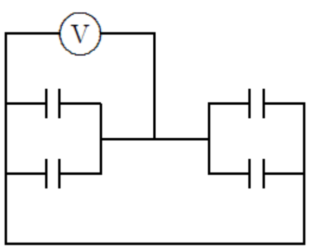

Figure 8

Physics 102
Formula sheet for Second Major

$\hat{i}, \hat{j}$ and $\hat{k}$ are unit vectors along the positive directions of x-axis, y-axis and z-axis respectively.

$F = \frac{kq_1q_2}{r^2}$, $F = q_0 E$

$\Phi = \int_{Surface} \vec{E} \cdot d\vec{A}$, $E = \frac{kq}{r^2}$

$E = \frac{kQ}{R^3} r$, $E = \frac{2k\lambda}{r}$

$\varphi_c = \oint \vec{E}.d\vec{A} = \frac{q_{in}}{\varepsilon_0}$; $E = \frac{\sigma}{2\varepsilon_o}$; $E = \frac{\sigma}{\varepsilon_o}$

$V = \frac{kQ}{r}$, $W = -\Delta U$

$\Delta V = V_B - V_A = -\int_A^B \vec{E}.d\vec{s} = \frac{\Delta U}{q_0}$

$E_x = -\frac{\partial V}{\partial x}, E_y = -\frac{\partial V}{\partial y}, E_z = -\frac{\partial V}{\partial z}$

$U = \frac{kq_1q_2}{r_{12}}$

$C = \frac{Q}{V}$, $C_o = \frac{\varepsilon_0 A}{d}$, $C = 4\pi\varepsilon_o \frac{ab}{b-a}$,

$U = \frac{1}{2} CV^2$, $u = \frac{1}{2}\varepsilon_o E^2$, $C = \kappa C_0$,

$\vec{\tau} = \vec{p} \times \vec{E}$, $U = -\vec{p} \cdot \vec{E}$

$v = v_o + at$

$x - x_o = v_o t + \frac{1}{2} at^2$

$v^2 = v_o^2 + 2a(x - x_o)$

$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N.m^2$
$k = 9.0 \times 10^9\ N.m^2/C^2$
$e = -1.6 \times 10^{-19}\ C$
$m_e = 9.11 \times 10^{-31}$ kg
$m_p = 1.67 \times 10^{-27}$ kg
1 eV = 1.6×10^{-19} J
g = 9.8 m/s^2

micro (μ) = 10^{-6}
nano (n) = 10^{-9}
pico (p) = 10^{-12}