Problem 1

A particular 12 V car battery can send a total charge of 84 A·h(ampere-hours) through a circuit, from one terminal to the other. (a) How many coulombs of charge does this represent? (b) If this entire charge undergoes a change in electric potential of 12 V, how much energy is involved? (02小題)

(a) ________ C

01: **ANS:=3E5**

$$84\ \text{A}\cdot\text{h} = \left(84\frac{\text{C}\cdot\text{h}}{\text{s}}\right)\left(3600\frac{\text{s}}{\text{h}}\right) = 3.0\times10^5\ \text{C}.$$

(b) ________ J

$$\Delta U = q\Delta V = (3.0\times10^5\ \text{C})(12\ \text{V}) = 3.6\times10^6\ \text{J}.$$

02: **ANS:=3.6E6**

An infinite nonconducting sheet has a surface charge density σ =0.1 μC/m^2 on one side. How far apart are equipotential surfaces whose potentials differ by 50 V? (01小題)

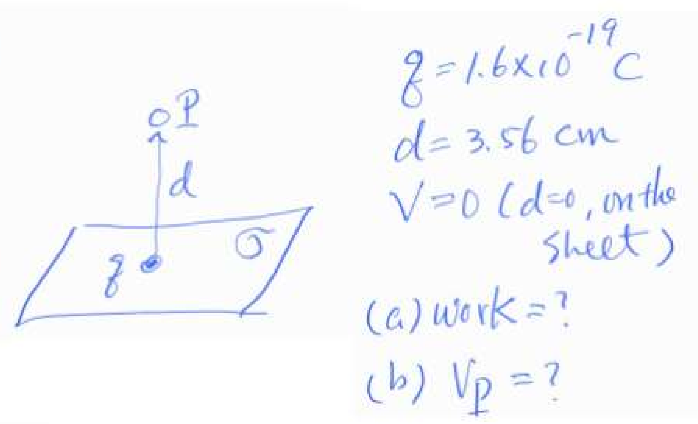
$$V = V_s - \int_0^x E\,dx = V_s - Ex.$$

$$\Delta V = E\Delta x = (\sigma/2\varepsilon_0)\Delta x.$$

$$\Delta x = \frac{2\varepsilon_0\Delta V}{\sigma} = \frac{2(8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2)(50\ \text{V})}{0.10\times10^{-6}\ \text{C}/\text{m}^2} = 8.8\times10^{-3}\ \text{m}.$$

Problem 2

An infinite nonconducting sheet has a surface charge density $\sigma = +5.8\ \mathrm{pC}/m^2$. (a) How much work is done by the electric field due to the sheet if a particle of charge $q = +1.6 \times 10^{-19}$ C is moved from the sheet to a point P at distance d=3.56 cm from the sheet? (b) If the electric potential V is defined to be zero on the sheet, what is V at P ? (02小題)



(a) ________ J

04: **ANS:=<u>1.87E-21</u>**

(b) ________ V

05: **ANS:=<u>-1.17E-2</u>**

(a) The work done by the electric field is

$$W=\int_i^f q_0\vec{E}\cdot d\vec{s}=\frac{q_0\sigma}{2\varepsilon_0}\int_0^d dz=\frac{q_0\sigma d}{2\varepsilon_0}=\frac{(1.60\times10^{-19}\,\mathrm{C})(5.80\times10^{-12}\,\mathrm{C/m^2})(0.0356\,\mathrm{m})}{2(8.85\times10^{-12}\,\mathrm{C^2/N\cdot m^2})}$$
$$=1.87\times10^{-21}\,\mathrm{J}.$$

(b) Since $V - V_0 = -W/q_0 = -\sigma z/2\varepsilon_0$, with V_0 set to be zero on the sheet, the electric potential at P is

$$V=-\frac{\sigma z}{2\varepsilon_0}=-\frac{(5.80\times10^{-12}\,\mathrm{C/m^2})(0.0356\,\mathrm{m})}{2(8.85\times10^{-12}\,\mathrm{C^2/N\cdot m^2})}=-1.17\times10^{-2}\,\mathrm{V}.$$

Problem 2

The electric field in a region of space has the components $E_y = E_z = 0$ and $E_x =$ (4.00 N/C)x. Point A is on the y axis at $y = 4$ m , and point B is on the x axis at x = 4 m. What is the potential difference V_B-V_A ? (01小題)

V_B-V_A= ________ V

06: **ANS:=-32**

We connect A to the origin with a line along the y axis, along which there is no change of potential (Eq. 24-18: $\int \vec{E} \cdot d\vec{s} = 0$). Then, we connect the origin to B with a line along the x axis, along which the change in potential is

$$\Delta V = -\int_0^{x=4} \vec{E} \cdot d\vec{s} = -4.00 \int_0^4 x\,dx = -4.00\left(\frac{4^2}{2}\right)$$

which yields $V_B - V_A = -32.0$ V.

Problem 3

The potential on the surface of a charged conducting sphere(with net charge Q) is given by

$$V(R) = \frac{kQ}{R}. \quad (\text{with} V = 0 \text{ at infinity})$$

What are (a) the charge and (b) the charge density on the surface of a conducting sphere of radius 0.15 m whose potential is 200 V ? (02小題)

(a) the charge = ________ C

07: **ANS:=3.3E-9**

(b) the charge density = _____

08: **ANS:=1.2E-8**

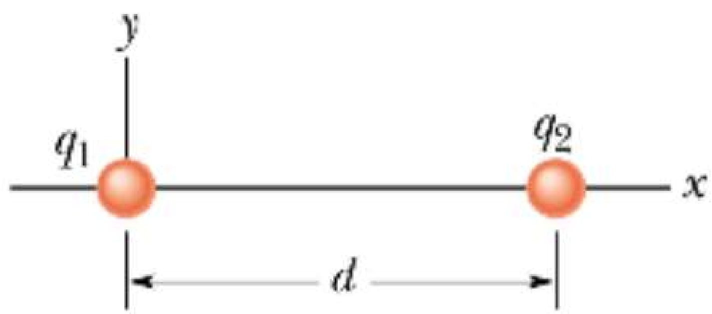
(a) The charge on the sphere is

$$q = 4\pi\varepsilon_0 VR = \frac{(200 \text{ V})(0.15 \text{ m})}{8.99\times10^9 \text{ N}\cdot\text{m}^2/\text{C}^2} = 3.3\times10^{-9} \text{ C}.$$

(b) $$\sigma = \frac{q}{4\pi R^2} = \frac{3.3\times10^{-9} \text{ C}}{4\pi(0.15 \text{ m})^2} = 1.2\times10^{-8} \text{ C/m}^2.$$

Problem 3

In the figure, particles of the charges $q_1 = +5e$ and $q_2 = -15e$ are fixed in place with a separation of $d = 24$ cm . With $V = 0$ at infinity, what are the finite (a) positive and (b) negative values of x at which the net electric potential on the x axis is zero? (02小題)



(a) $x > 0$ ________ cm

09: **ANS:=6**

(b) $x < 0$ ________ cm

10: **ANS:=-12**

$V(x)$ cannot be equal to zero for $x > d$.

we consider $x < 0$ and $0 < x < d$.

$0 < x < d \quad d_1 = x$ and $d_2 = d - x$.

$$V(x) = k\left(\frac{q_1}{d_1} + \frac{q_2}{d_2}\right) = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{x} + \frac{-3}{d-x}\right) = 0$$

$x = d/4$. With $d = 24.0$ cm, we have $x = 6.00$ cm.

$d_1 = -x; \quad d_2 = d - x.$

$$V(x) = k\left(\frac{q_1}{d_1} + \frac{q_2}{d_2}\right) = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{-x} + \frac{-3}{d-x}\right) = 0$$

$x = -d/2$. With $d = 24.0$ cm, we have $x = -12.0$ cm.

Problem 4

A spherical drop of water carrying a charge of 30 pC has a potential of 500 V at its surface (with V=0 at infinity). (a) What is the radius of the drop? (b) If two such drops of the same charge and radius combine to form a single spherical drop, what is the potential at the surface of the new drop? (02小題)

(a) the radius of the drop= ________ m

11: **ANS:=5.4E-4**

(b) the potential= ________ V

12: **ANS:=793.7**

$$V = q/4\pi\varepsilon_0 R.$$

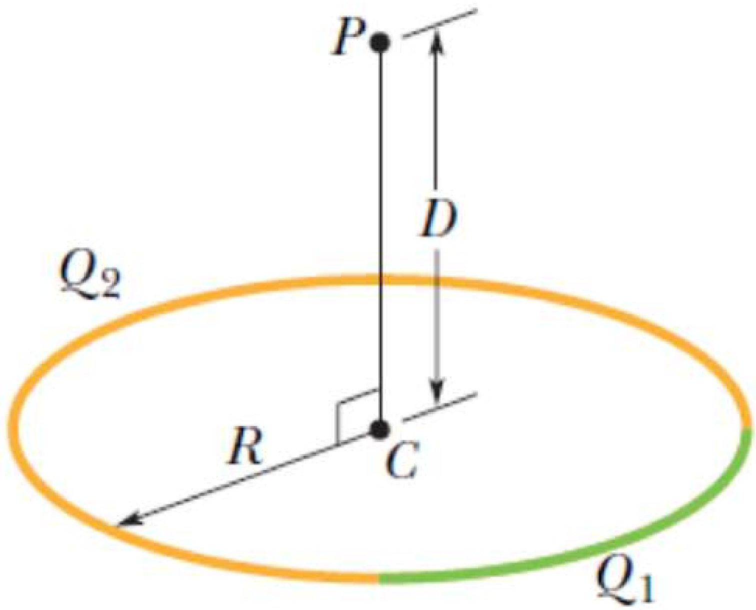
$$R = \frac{q}{4\pi\varepsilon_0 V} = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(30\times10^{-12}\ \text{C})}{500\ \text{V}} = 5.4\times10^{-4}\ \text{m}.$$

$$(R')^3 = 2R^3 \text{ and } R' = 2^{1/3}R.$$

$$V' = \frac{1}{4\pi\varepsilon_0}\frac{q'}{R'} = \frac{1}{4\pi\varepsilon_0}\frac{2q}{2^{1/3}R} = 2^{2/3}V = 2^{2/3}(500\ \text{V}) \approx 790\ \text{V}.$$

Problem 5

A plastic rod has been bent into a circle of radius R =8.2 cm. It has a charge Q_1 = 4.2 pC uniformly distributed along one-quarter of its circumference and a charge Q_2 = -6Q_1 uniformly distributed along the rest of the circumference (the figure).With V=0 at infinity, what is the electric potential (a) at the center C of the circle and (b) at point P, which is on the central axis of the circle at distance D = 6.71 cm from the center? (02小題)



(a) the electric potential= ________ V

$$V=\frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1}{R}-\frac{6Q_1}{R}\right)=-\frac{5Q_1}{4\pi\varepsilon_0 R}$$

13: **ANS:=-2.3**

(b) the electric potential= ________ V

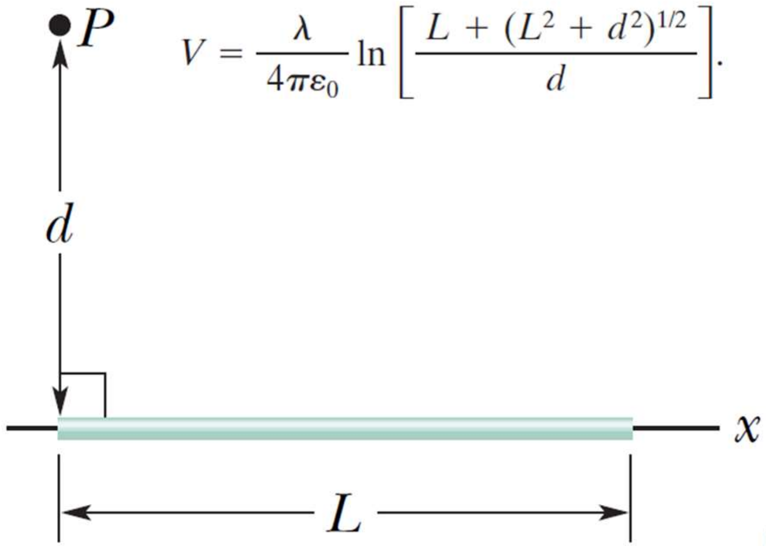
$$=-\frac{5(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(4.20\times10^{-12}\ \text{C})}{8.20\times10^{-2}\ \text{m}}=-2.30\ \text{V}.$$

14: **ANS:=-1.78**

$$V=\frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{\sqrt{R^2+D^2}}-\frac{6Q_1}{\sqrt{R^2+D^2}}\right]=-\frac{5Q_1}{4\pi\varepsilon_0\sqrt{R^2+D^2}}=-\frac{5(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(4.20\times10^{-12}\ \text{C})}{\sqrt{(8.20\times10^{-2}\ \text{m})^2+(6.71\times10^{-2}\ \text{m})^2}}=-1.78\ \text{V}.$$

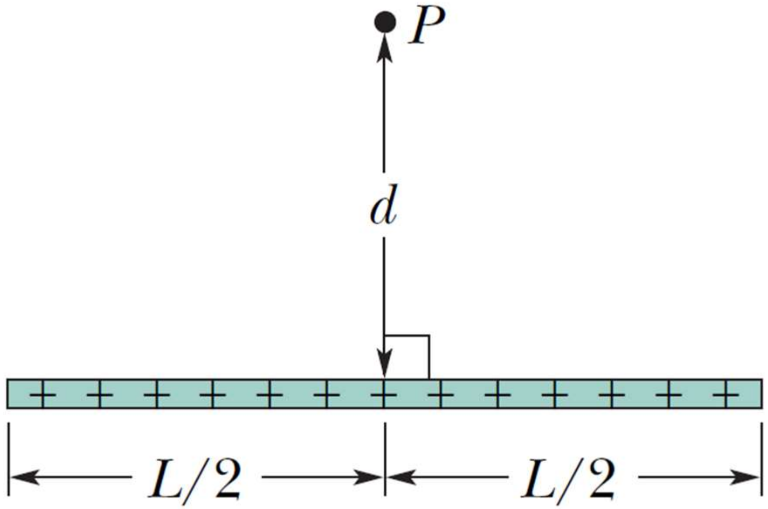
Problem 6

Figure(a) shows a nonconducting rod of length L. The electric potential at P is given with formula in the figure. Now we consider the rod in Figure(b) which has $L = 6$ cm and uniform linear charge density λ= +3.68 pC/m .Take V=0 at infinity. What is V at point P at distance d=8 cm along the rod's perpendicular bisector? We set V=0 at infinity. (01小題)



$$V = \frac{\lambda}{4\pi\varepsilon_0} \ln\left[\frac{L + (L^2 + d^2)^{1/2}}{d}\right].$$

(a)



(b)

V_P=________ V

15: **ANS:=2.43E-2**

$$V = 2\frac{\lambda}{4\pi\varepsilon_0}\ln\left[\frac{L/2+\sqrt{(L^2/4)+d^2}}{d}\right]$$

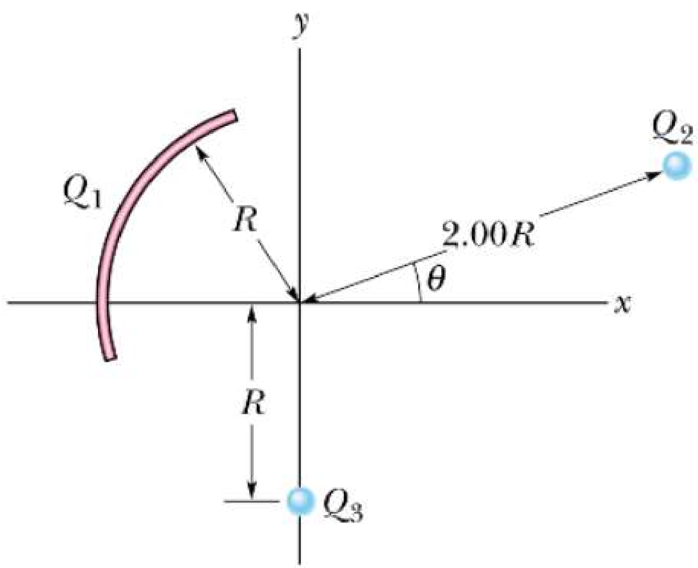
$$= 2(8.99\times10^9\ \mathrm{N\cdot m^2/C^2})(3.68\times10^{-12}\ \mathrm{C/m})$$

$$\ln\left[\frac{(0.06\ \mathrm{m}/2)+\sqrt{(0.06\ \mathrm{m})^2/4+(0.08\ \mathrm{m})^2}}{0.08\ \mathrm{m}}\right]$$

$$= 2.43\times10^{-2}\ \mathrm{V}.$$

Problem 7

In the figure, what is the net electric potential at the origin due to the circular arc of charge Q_1= +7.21 pC and the two particles of charges Q_2=4Q_1 and Q_3=-2 Q_1 ? The arc's center of curvature is at the origin and its radius is R=2 m ; the angle indicated is θ=20°. (01小題)



the net electric potential=________ V

16: **ANS:=3.24E-2**

$$V \to 0 \text{ as } r \to \infty$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{+Q_1}{R} + \frac{1}{4\pi\varepsilon_0}\frac{+4Q_1}{2R} + \frac{1}{4\pi\varepsilon_0}\frac{-2Q_1}{R} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1}{R}$$

$$= \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(7.21\times10^{-12}\ \text{C})}{2.00\ \text{m}} = 3.24\times10^{-2}\ \text{V}.$$

Problem 8

The electric potential at points in an xy plane is given by $V = (2.0\,\mathrm{V/m^2})x^2 - (3.0\,\mathrm{V/m^2})y^2$. In unit-vector notation, what is the electric field at the point (3.0 m, 2.0 m)? (02小題)

$\vec{E} = E_x\hat{i} + E_y\hat{j}$,

E_x=____ V/m

17: **ANS:=<u>-12</u>**

E_y=____ V/m

18: **ANS:=<u>12</u>**

$$E_x(x,y) = -\frac{\partial V}{\partial x} = -\frac{\partial}{\partial x}\left((2.0\mathrm{V/m^2})x^2 - 3.0\mathrm{V/m^2})y^2\right) = -2(2.0\mathrm{V/m^2})x;$$

$$E_y(x,y) = -\frac{\partial V}{\partial y} = -\frac{\partial}{\partial y}\left((2.0\mathrm{V/m^2})x^2 - 3.0\mathrm{V/m^2})y^2\right) = 2(3.0\mathrm{V/m^2})y.$$

We evaluate at x = 3.0 m and y = 2.0 m to obtain

$$\vec{E} = (-12\ \mathrm{V/m})\hat{\text{i}} + (12\ \mathrm{V/m})\hat{\text{j}}.$$

What is the magnitude of the electric field at the point (3,-2,4) m if the electric potential is given by $V = 2xyz^2$, where V is in volts and x, y, and z are in meters? (01小題)

$|\vec{E}|$=____ N/C

19: **ANS:=<u>150</u>**

$$E_x = -\frac{\partial V}{\partial x} = -2.00yz^2$$

$$E_y = -\frac{\partial V}{\partial y} = -2.00xz^2$$

$$E_z = -\frac{\partial V}{\partial z} = -4.00xyz$$

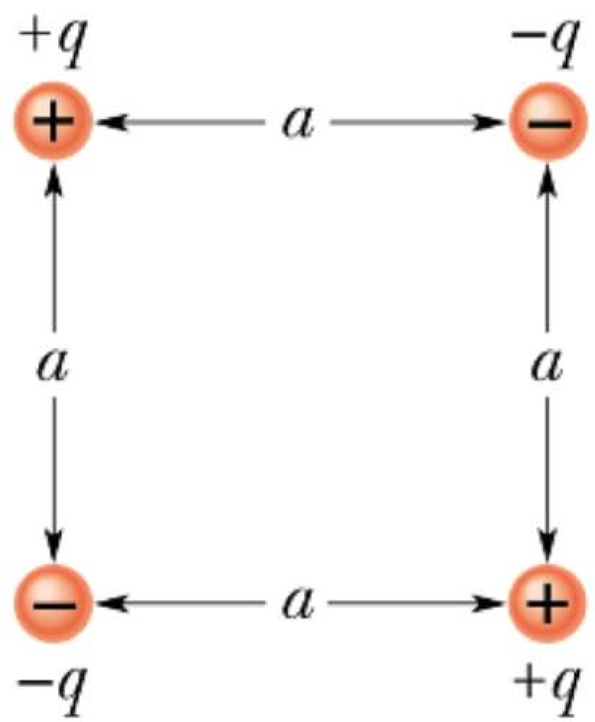
at (x, y, z) = (3.00 m, –2.00 m, 4.00 m)

(E_x, E_y, E_z) = (64.0 V/m, –96.0 V/m, 96.0 V/m).

$$|\vec{E}| = \sqrt{E_x^2 + E_y^2 + E_z^2} = 150\,\mathrm{V/m} = 150\,\mathrm{N/C}.$$

Problem 9

How much work is required to set up the arrangement of the figure if q= 2.3 pC , a=64 cm, and the particles are initially infinitely far apart and at rest? (01小題)



________ V

20: **ANS:=-1.92E-13**

$$U_f = \frac{q^2}{4\pi\varepsilon_0}\left(-\frac{1}{a}-\frac{1}{a}+\frac{1}{\sqrt{2}a}-\frac{1}{a}-\frac{1}{a}+\frac{1}{\sqrt{2}a}\right)=\frac{2q^2}{4\pi\varepsilon_0 a}\left(\frac{1}{\sqrt{2}}-2\right).$$

$$W=\Delta U=U_f-U_i=U_f=\frac{2q^2}{4\pi\varepsilon_0 a}\left(\frac{1}{\sqrt{2}}-2\right)=\frac{2(8.99\times10^9\ \mathrm{N\cdot m^2/C^2})(2.30\times10^{-12}\ \mathrm{C})^2}{0.640\ \mathrm{m}}\left(\frac{1}{\sqrt{2}}-2\right)$$

$$=-1.92\times10^{-13}\ \mathrm{J}.$$

Problem 10

A particle of charge $+7.5\mu\text{C}$ is released from rest at the point $x = 60$ cm on an x axis. The particle begins to move due to the presence of a charge Q that remains fixed at the origin. What is the kinetic energy of the particle at the instant it has moved 40 cm if (a) $Q = +20\mu\text{C}$ and (b) $Q = -20\mu\text{C}$? (02小題)

(a)For $Q = +20\mu$C, the kinetic energy =________ J

21: **ANS:=<u>0.9</u>**

(b)For $Q = -20\mu$C, the kinetic energy =________ J

22: **ANS:=<u>4.5</u>**

$$U_0 = K_f + U_f, \qquad U = \frac{qQ}{4\pi\varepsilon_o r}. \qquad q = 7.5\times10^{-6}\text{ C}$$

(a) The initial value of r is 0.60 m and the final value is (0.6 + 0.4) m = 1.0 m (since the particles repel each other). Conservation of energy, then, leads to $K_f = 0.90$ J.

(b) Now the particles attract each other so that the final value of r is 0.60 – 0.40 = 0.20 m. Use of energy conservation yields $K_f = 4.5$ J in this case.

Problem 11

What is the escape speed for an electron initially at rest on the surface of a sphere with a radius of 1.0 cm and a uniformly distributed charge of 1.6×10^{-15} C? That is, what initial speed must the electron have in order to reach an infinite distance from the sphere and have zero kinetic energy when it gets there? (01小題)

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the speed= _______ m/s

23: **ANS:=<u>22490</u>**

The *escape speed* may be calculated from the requirement that the initial kinetic energy (of *launch*) be equal to the absolute value of the initial potential energy (compare with the gravitational case in chapter 14). Thus,

$$\frac{1}{2}mv^2 = \frac{eq}{4\pi\varepsilon_0 r}$$

where $m = 9.11 \times 10^{-31}$ kg, $e = 1.60 \times 10^{-19}$ C, $q = 10000e$, and $r = 0.010$ m. This yields $v = 22490$ m/s $\approx 2.2\times10^4$ m/s .

Problem 12

Two electrons are fixed d=2.0 cm apart. Another electron is shot from infinity and stops midway between the two. What is its initial speed? mass of electron $m = 9.1 \times 10^{-31}$ kg. (01小題)

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initial speed, v_i=_____ m/s

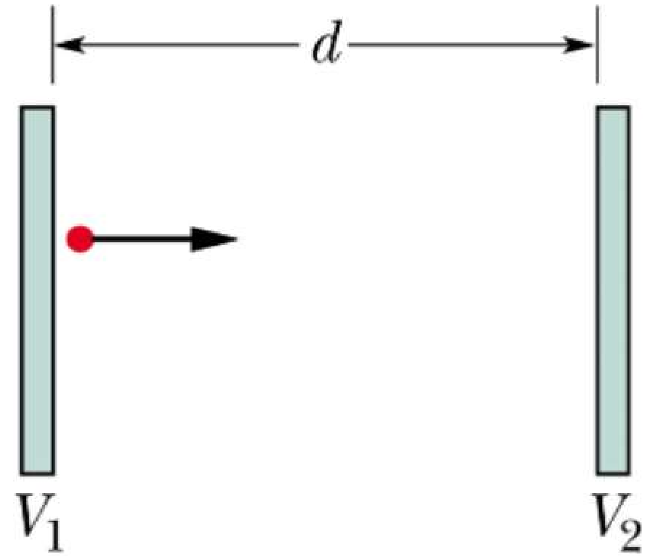
24: **ANS:=<u>320</u>**

$$\frac{1}{2}mv^2 = 2 \times \frac{e^2}{4\pi\epsilon_0 d}$$

$$v = \sqrt{\frac{4e^2}{4\pi\epsilon_0 dm}}$$

Problem 13

In the figure, a charged particle (either an electron or a proton) is moving rightward between two parallel charged plates separated by distance d=2 mm . The plate potentials are V_1=-70 V and V_2=-50 V . The particle is slowing from an initial speed of 90 km/s at the left plate. (a) What is its speed just as it reaches plate 2? (01小題)



________ m/s

25: **ANS:=6.53E4**

(a) The electric field between the plates is leftward since it points towards lower values of potential. The force is evidently leftward, from the problem description (indicating deceleration of the rightward moving particle), so that $q > 0$ (ensuring that $\vec{F}$ is parallel to $\vec{E}$); it is a proton.

(b) We use conservation of energy:

$$K_0 + U_0 = K + U \Rightarrow \frac{1}{2} m_p v_0^2 + qV_1 = \frac{1}{2} m_p v^2 + qV_2 .$$

Using $q = +1.6 \times 10^{-19}$ C, $m_p = 1.67 \times 10^{-27}$ kg, $v_0 = 90 \times 10^3$ m/s, $V_1 = -70$ V and $V_2 = -50$ V, we obtain the final speed $v = 6.53 \times 10^4$ m/s. We note that the value of d is not used in the solution.