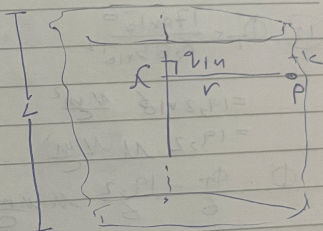


16/10
cylindrical symmetry
(infinite line, cylinder)

① infinite line very long linear charged density (λ)

$$\lambda = \frac{q_{in}}{L}$$

$$q_{in} = \lambda L$$



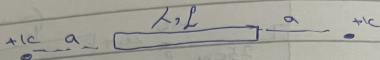
$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0}$$

$$E(2\pi r L) = \frac{\lambda L}{\epsilon_0}$$

$$E = \frac{\lambda}{2\pi \epsilon_0 r}$$

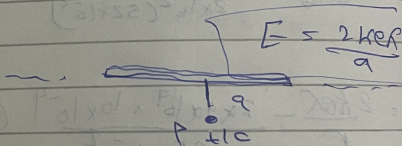
$E = \frac{\lambda}{2\pi \epsilon_0 r}$	infinite λ (line)
---	---------------------------

Rod $\xrightarrow{\text{ch28}}$ Finite Rod $\rightarrow$ length known
 $\rightarrow$ Find electric field along the Rod



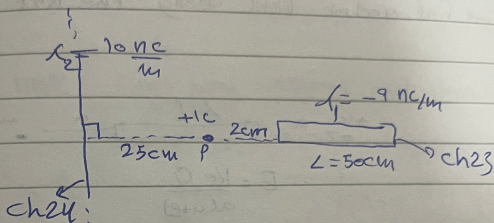
$$E = \frac{KQ}{a(a+L)}$$

Infinite line (Rod) $\xrightarrow{\text{ch24}}$ length infinite
 $\rightarrow$ Find electric field a distance r perpendicular from the line



$$E = \frac{2k\sigma r}{a}$$

cylindrical symmetry



Find the electric field at the point P

$$E_1 = \frac{k\lambda L}{r(a+b)} = \frac{9 \times 10^9 \times 10 \times 10^{-9}}{2 \times 10^{-2} (52 \times 10^{-2})} (+\hat{r})$$

$$E_2 = \frac{2k\lambda L}{r} = \frac{2 \times 9 \times 10^9 \times 10 \times 10^{-9}}{25 \times 10^{-2}} (+\hat{r})$$

$$E_P = E_1 + E_2$$

التاريخ / /
long = infinit

اليوم

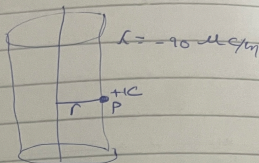
موضوع الدرس

$$E = \frac{2k\lambda x}{r}$$

$$r = 20 \text{ cm}$$

$$= \frac{2 \times 9 \times 10^9 \times 90 \times 10^{-6}}{0.2} \frac{\text{N}}{\text{C}}$$

"Inward"

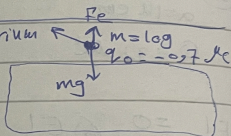


(25)

In equilibrium

$$\Sigma =$$

$$Q =$$



$$\Sigma F = 0$$

$$F_e = mg$$

$$\frac{1}{2} \epsilon_0 E_0 = mg$$

$$\frac{1}{2} \frac{\sigma}{\epsilon_0} = mg$$

$$\sigma = \frac{2 \epsilon_0 mg}{q_0} = \frac{2 \times 8.85 \times 10^{-12} \times 10 \times 10^{-3}}{0.7 \times 10^{-6}} \frac{\text{C}}{\text{m}^2}$$

Infinite plastic sheet

$$\Sigma F = 0$$

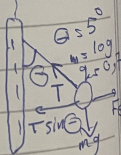
$$T \sin \theta = F_e$$

$$T \cos \theta = mg$$

$$\tan \theta = \frac{F_e}{mg}$$

$$E_0 = \frac{\sigma}{\epsilon_0} = \frac{mg \tan \theta}{q_0}$$

non-conducting
long sheet



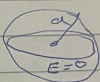
(29)



(29)

$$a = 14 \text{ cm}$$

$$Q = 32 \text{ nC}$$



$$a) E = 0 \quad r = 10 \text{ cm}$$

بالداخل

$$b) E \quad r = 20 \text{ cm}$$

بالخارج

spherical shell
قشرة كروية
(معدنية)

$$E = \frac{kQ}{r^2} = \frac{4 \times 10^9 \times 32 \times 10^{-6}}{0.2^2} \quad \frac{1}{c} \text{ (outwards)}$$

$r = 20$

30) Non-conducting wall

$$\sigma = 8.6 \mu\text{C}/\text{m}^2$$

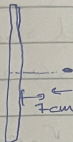
$$E = \frac{\sigma}{2\epsilon_0}$$

$$r = 7\text{cm}$$

أو $7 \times 10^{-2}\text{m}$

$$= \frac{8.6 \times 10^{-6}}{2 \times 8.85 \times 10^{-12}}$$

1/c "outwards"

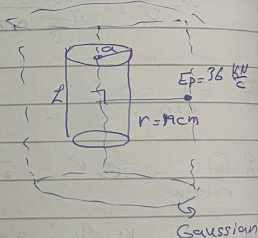


34) $a = 7\text{cm}$, $L = 2\text{km}$

$$\oint E dA = \frac{q_{\text{in}}}{\epsilon_0}$$

$$E(2\pi rL) = \frac{q_{\text{in}}}{\epsilon_0}$$

$$E = \frac{q_{\text{in}}}{2\pi rL\epsilon_0}$$



$$q_{\text{in}} = 2\pi (0.07)(2000)(8.85 \times 10^{-12}) \times (36 \times 10^3)$$

$$= 912 \times 10^{-9}\text{C}$$

b) surface charge density

$$\sigma = \frac{q}{A} = \frac{912}{\pi (0.07)^2 (2000)} \text{ nC}/\text{m}^2$$

$$\textcircled{c} E = 0$$

$$r = 4 \text{ cm}$$

35) solid sphere

$$R = 40 \text{ cm} \rightarrow Q = 26 \text{ } \mu\text{C}$$

Non-conducting
(Insulator)



Through the
Volume

$$\textcircled{a} E = \frac{\rho}{3\epsilon_0} r, \quad r < R$$

$$\rho = \frac{Q}{V} = \frac{26 \times 10^{-6}}{\frac{4\pi}{3} (4)^3} = 97 \text{ } \mu\text{C/m}^3$$

$$\textcircled{a} E = 0$$

$$r = 0$$

$$\textcircled{b} E = \frac{\rho}{3\epsilon_0} r = \frac{97}{3 \times 8.85 \times 10^{-12}} (0.1) \text{ (Coul)}$$

$$\textcircled{c} E = k_e \frac{q}{r^2} = 9 \times 10^9 \times \frac{26 \times 10^{-6}}{(0.4)^2}$$

$$r = 40 \text{ cm}$$

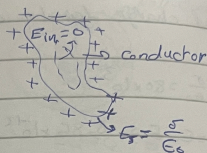
مساحة
الكرة

$$0 E = k_e \frac{Q}{r^2} = 9 \times 10^9 \times \frac{26 \times 10^{-6}}{(0.6)^2}$$

$$r = 60 \text{ cm}$$

مساحة
الكرة

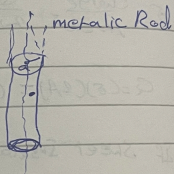
- Conductor in electrostatic Equilibrium



(37) $a = 5 \text{ cm}$, $\lambda = 30 \frac{\text{nc}}{\text{m}}$

$E = 0$
 $r = 3 \text{ cm}$

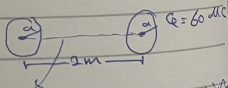
$E = \frac{2k\lambda r}{r} = \frac{2 \times 9 \times 10^9 \times 30 \times 10^{-9}}{0.03}$



(43) $a = 0.5$

Identical conducting spheres

Find the Tension



very thin conducting wire

$U_{\text{system}} = U_{\text{system}}$

$Q_1 + Q_2 = Q_1 + Q_2$

$60 + 0 = 2Q$

$Q = \frac{60}{2} = 30 \text{ nC}$

Tension $F_e = \frac{kQ^2}{r^2}$

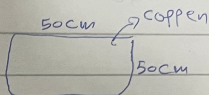
$= \frac{9 \times 10^9 \times (30 \times 10^{-9})^2}{2^2}$

Repulsive

(44)

$$E = 80 \text{ kN/C}$$

Find charge density each face



$$E = \frac{\sigma}{\epsilon_0} = 80 \times 10^3$$

$$\sigma = \epsilon_0 E = 8.85 \times 10^{-12} \times 80 \times 10^3 = 708 \text{ nC/m}$$

$$\sigma = \frac{\text{Charge}}{\text{Area}} = \frac{Q}{2A (\text{conductor})}$$

$$Q = (\sigma)(2A) = (708)(2 \times 0.5^2)$$

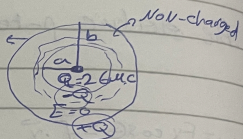
If Sheet Insulator

$$\sigma = \frac{Q}{A} \quad E = \frac{\sigma}{2\epsilon_0}$$

Induced charge

شحن بالحث

conducting
spherical
shell



inner radius = a

outer radius = b

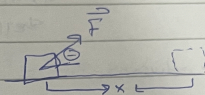
$$-Q + Q = 0$$

شحن الايجابية ومساوية بالاعتبار

Ch 25 The electric potential

the electric potential energy:

$$W = Fx \cos \theta = \vec{F} \cdot \vec{x}$$



If $\vec{F} = F(x)$

$$W = \int_a^b F(x) \cdot dx$$

The change in potential energy

$$W = -\Delta U$$

$$\textcircled{A} \rightarrow \textcircled{B} \quad \textcircled{A} \rightarrow \textcircled{B}$$

$$\Delta K + \Delta U = 0$$

$$KE = \frac{1}{2}mv^2$$

What is the electric work
moving the charged particle
from $\textcircled{A} \rightarrow \textcircled{B}$



$$W_{A \rightarrow B} = \int_A^B \vec{E}(r) \cdot d\vec{r} \quad ; \quad d\vec{r} = \begin{cases} \pm dx \hat{i} \\ \pm dy \hat{j} \end{cases}$$

$$W_{A \rightarrow B} = - \int_A^B q_0 \vec{E} \cdot d\vec{r}$$

→ energy difference

$$\Delta U_{A \rightarrow B} = -W_{A \rightarrow B} = -q_0 \int_A^B \vec{E} \cdot d\vec{r}$$

→ The electric potential difference

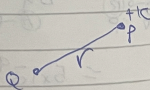
$$\Delta V_{A \rightarrow B} = \frac{\Delta U_{A \rightarrow B}}{q_0} = \frac{U_B - U_A}{q_0}$$

$$\Delta V_{A \rightarrow B} = - \int_A^B \vec{E} \cdot d\vec{r}$$

Ex: the electric potential of a point charge

$$\Delta V = - \int \vec{E} \cdot d\vec{r} = - \int \frac{k_e Q}{r^2} dr$$

$$V = \frac{k_e Q}{r} \quad ; \quad r \rightarrow \infty \quad V = 0$$

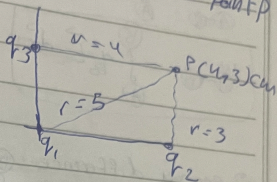


Exi (a) Find the electric potential at the point P shown in the figure

$$q_1 = -10 \mu\text{C}$$

$$q_2 = 27 \mu\text{C}$$

$$q_3 = -16 \mu\text{C}$$



$$V_P = V_1 + V_2 + V_3 \quad \text{and} \quad V = K_e \frac{Q}{r} \rightarrow 0.9 \times 10^6$$

$$= K_e \frac{q_1}{r_1} + K_e \frac{q_2}{r_2} + K_e \frac{q_3}{r_3}$$

$$= \frac{9 \times 10^9 \times 10^{-6}}{5} \left[-\frac{10}{5} + \frac{27}{3} + \frac{-16}{4} \right]$$

$$= 9 \times 10^5 [-2 + 9 - 4] = 27 \times 10^5 = 2.7 \text{ MV}$$

(b) What is the work required to bring a charge $q_0 = -5 \text{ nC}$ from infinity to the point P?

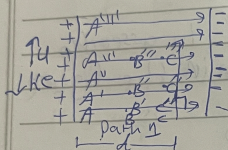
$$dV = \frac{dU}{q_0}$$

$$W_{\infty \rightarrow P} = -\Delta U = -q_0 \Delta V = -q_0 (V_P - V_\infty)$$

$$= 5 \times 10^{-9} \times 2.7 \times 10^6 = 13.5 \text{ mJ}$$

→ the equi-potential Surfaces

سطح تساوي الجهد



KE ↑

U ↓

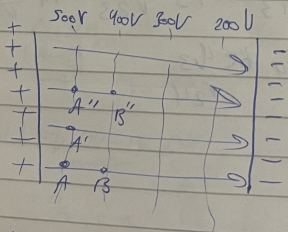
$$\Delta U = U - U_0$$

$$= -W_{A \rightarrow A''} = - \int_A^{A''} \vec{E} \cdot d\vec{r}$$

$$\Delta U_{AB} = - \int_A^B \vec{E} \cdot d\vec{r} - \int_C^{A''} \vec{E} \cdot d\vec{r}$$

$$= - \int (\vec{E} \cdot \vec{\nabla}) \cdot (dx \hat{i}) - \int \rho / \epsilon_0$$

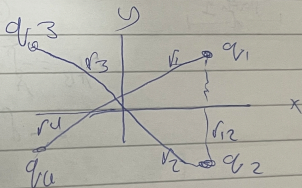
$$\Delta U_{A \rightarrow \odot} = -Ed + 0$$



$$\Delta U + \Delta KE = 0$$

What is the energy stored in the system of charged particles shown in the figure?

What is the work required to assemble the charged particles shown in the figure?

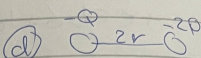
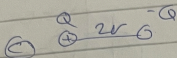
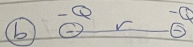
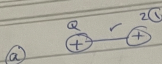


$$U = q_2 \frac{K_e q_1}{r_{12}} + q_3 \frac{K_e q_1}{r_{13}} + q_3 \frac{K_e q_2}{r_{23}} + q_4 \frac{K_e q_1}{r_{24}}$$

$$+ q_4 \frac{K_e q_2}{r_{24}} + q_4 \frac{K_e q_3}{r_{24}}$$

$$U = \frac{K_e q_i q_j}{r_{ij}}$$

5
767



Rank potential energy from greatest to smallest

$$U_a = k_e \frac{2Q^2}{r} = \frac{2 k_e Q^2}{r}$$

$$U_b = k_e \frac{(-Q)(-Q)}{r} = \frac{k_e Q^2}{r}$$

$$U_c = \frac{k_e Q(-Q)}{2r} = -\frac{k_e Q^2}{2r} \quad U_a > U_b = U_d > U_c$$

$$U_d = \frac{k_e (-Q)(-2Q)}{2r} = \frac{k_e Q^2}{r}$$

2
769

$$\Delta U = q_0 \Delta V$$

$$q_0 = 12 \mu\text{C}, \quad \vec{E} = 250 \hat{j} \text{ V/m}$$

$$\Delta U = q_0 \Delta V = q_0 \int_{\vec{r}_i}^{\vec{r}_f} \vec{E} \cdot d\vec{r}$$

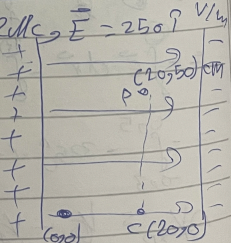
$$\Delta U = q_0 \int_{\vec{r}_i}^{\vec{r}_f} \vec{E} \cdot d\vec{r}$$

$$= q_0 \int_{\vec{r}_i}^{\vec{r}_f} \vec{E} \cdot d\vec{r}$$

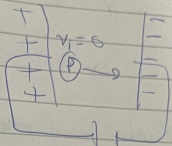
$$= - \int_{\vec{r}_i}^{\vec{r}_f} (250 \hat{j}) \cdot (dx \hat{i}) + 0$$

$$= -(250 \times 0.2) = -50 \text{ J} = q_0 \Delta V$$

$$\Delta V = \frac{-50}{q_0} = \frac{-50}{12 \times 10^{-6}} \text{ V}$$



proton $m_p = 1.67 \times 10^{-27}$
 $+e = 1.6 \times 10^{-19} \text{ C}$



$$\Delta U + \Delta K = 0$$

$$\Delta U = q_0 \Delta V, K = \frac{1}{2} m v^2$$

$$q_0 \Delta V + \left(\frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 \right) = 0$$

$$\Delta V = 120 \text{ V}$$

$$v_f = \sqrt{\left| \frac{2 q_0 \Delta V}{m_p} \right|} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 120}{1.67 \times 10^{-27}}} \text{ m/s}$$

$$V_B - V_A = ?$$

or
 $(0.2, 0.5)$
 PC

B
 $(0.5, 0.5)$

$$\Delta V_{AB} = V_B - V_A = - \int_A^B \vec{E} \cdot d\vec{r}$$

$$= - \int_A^B \vec{E} \cdot d\vec{r} = - \int_C^D \vec{E} \cdot d\vec{r}$$

$$(0.2, 0.3) \rightarrow (0.5, 0.3) \quad \vec{E} = 325(-) \hat{y} \text{ m}$$

$$= - \int_{0.3}^{0.5} 325 \cdot (+dy) = - \int_{0.2}^{0.5} 325 \cdot (dx)$$

$$\Delta V_{AB} = V_B - V_A = 325(0.28) = 260 \text{ V}$$

2f $\vec{E} = 300\hat{i} - 400\hat{j}$

$$DV_{A \rightarrow B} = - \int_A^B \vec{E} \cdot d\vec{r} = - \int_C^D \vec{E} \cdot d\vec{r}$$

$$= - \int_{-0.3}^{0.5} (300\hat{i} - 400\hat{j}) \cdot (dx\hat{i}) = - \int_{-0.3}^{0.5} (300) dx$$

$$= 400(0.8) - 300(0.8) \text{ V}$$

(F)
769

electron

$$\Delta U + \Delta K = 0$$

$$\Delta U = -\Delta K$$

$$q_0 \Delta V = -\left(\frac{1}{2} m (v_f^2 - v_i^2)\right)$$

$$q_0 \Delta V = -\frac{1}{2} (9.11 \times 10^{-31}) ((1.2 \times 10^5)^2 - (3.7 \times 10^6)^2) \quad V_B = ?$$

$$\Delta V = -V_e$$

$$V_0 - V_B =$$

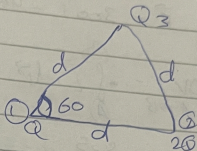
$$v_i = 3.7 \times 10^6 \text{ m/s} \quad v_f = 1.2 \times 10^5 \text{ m/s}$$

+			
+	⊙	⊙	-
+	x=0	x=2cm	-
+	0	B	-

16
770

$$U = k_e \frac{qQ}{r}$$

Find an expression for the electric potential energy

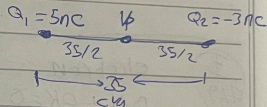


$$U = k_e \frac{2Q^2}{d} + k_e \frac{Q^2}{d} + k_e \frac{2Q^2}{d} = 5 k_e \frac{Q^2}{d}$$

16
770

$$V = k_e \frac{Q}{r}$$

$$V_p = V_1 + V_2 = \frac{9 \times 10^9 \times 10^{-9}}{35/10^{-2}} [5 - 3]$$



$$V = \frac{36 \times 10^2}{35} V$$

$$U = \frac{k_e q_1 q_2}{r} = \frac{9 \times 10^9 \times 5 \times 10^{-9} \times (-3 \times 10^{-9})}{0.35} \text{ J}$$

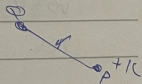
26
771

$$E_p = \frac{k_e Q}{r^2}$$

$$V_p = \frac{k_e Q}{r}$$

$$\frac{E_p}{V_p} = \frac{1}{r}$$

$$r = \frac{V_p}{E_p} = \frac{3000}{500} = 6 \text{ m}$$



$$-3000 = \frac{9 \times 10^9 \times Q}{6}$$

$$E_p = 500 \text{ V/m}$$

$$V_p = -3 \text{ kV} \\ = -3000 \text{ V}$$

$$Q = \dots$$

23
777

$$|E_1| = |E_2|$$

$$\frac{Kq}{x^2} = \frac{Kq(2q)}{(2-x)^2}$$

$$x \neq +1$$

$$x \neq 0 \quad E_p < 0$$

$$x > 1$$

$$-2q$$

$$x = 2$$

$$|V_1| = |V_2|$$

$$\frac{Kq}{x} = \frac{K(2q)}{2-x}$$

$$V(x, y, z) = 5x - 3x^2y + 2yz^2$$

$$E_x = -\frac{\partial V}{\partial x} = -[x - 6xy] = -5 + 6xy$$

$$E_y = -\frac{\partial V}{\partial y} = -[-3x^2 + 2z^2] = 3x^2 - 2z^2$$

$$E_z = -\frac{\partial V}{\partial z} = -4yz$$

$$\vec{E} = (6xy - 5)\hat{i} + (3x^2 - 2z^2)\hat{j} - 4yz\hat{k}$$

$$\vec{E}(1, 0, -2) = -5\hat{i} - 5\hat{j}$$

$$|E| = 5\sqrt{2} \quad V/m$$

∴ obtaining electric field from electric potential

$$\Delta V = - \int E dx$$

$$E = - \frac{\partial V}{\partial x}$$

$$\vec{E} = - \frac{\partial V}{\partial x} \hat{i} - \frac{\partial V}{\partial y} \hat{j} - \frac{\partial V}{\partial z} \hat{k}$$

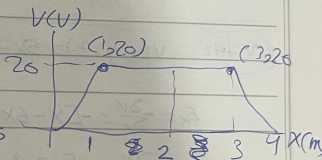
(36)
772

$$E = - \text{slope}$$

$$E_1 = \frac{V_2 - V_1}{x_2 - x_1} = \frac{20 - 0}{1 - 0} = -20$$

$$E_2 = 0$$

$$E_3 = - \frac{0 - 20}{4 - 3} = +20 \text{ V/m}$$

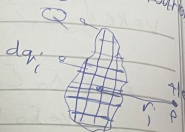


The electric potential acts charge distribution

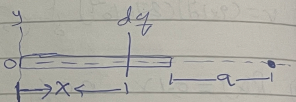
$$dV = k_e \frac{dq_i}{r_i}$$

$$V = \sum_i k_e \frac{dq_i}{r_i}$$

$$V = \int_{\text{charge}} k_e \frac{dq}{r}$$



Ex1



$$V = k_e \frac{dq}{(a+L-x)} ; dq = \lambda dx$$

+ charge density constant $\lambda = \lambda_0 = 27 \text{ nC/m}$

$$V = k_e \int \frac{\lambda(x) dx}{(a+L-x)}$$

$$\lambda(x) = \lambda_0$$

$$= k_e \lambda_0 \int_{x=0}^L \frac{dx}{a+L-x}$$

$$\int \frac{dx}{x} = \ln x$$

$$\int \frac{dx}{L+a} = \ln(L+a)$$

Sigma

$$\begin{aligned}
 V &= k_e \int_{a+L}^L \frac{\lambda_0}{a+L-x} dx = -k_e \lambda_0 \ln |a+L-x| \Big|_{a+L}^L \\
 &= -k_e \lambda_0 [\ln |a| - \ln |a+L|] \\
 &= k_e \lambda_0 \ln \left| \frac{a+L}{a} \right|
 \end{aligned}$$

Example $\lambda_0 = 27 \frac{nC}{m}$, $a = 1cm$, $L = 20cm$

$$a) V = (9 \times 10^9) (27 \times 10^9) \int_0^{0.2} \frac{dx}{0.21-x}$$

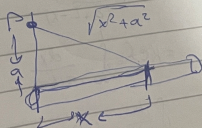
$$b) \lambda(x) = 0.1x \text{ nC/m}$$

$$V = 9 \times 10^9 \int_0^{0.2} \frac{0.01 + 10^9}{0.21-x} dx$$

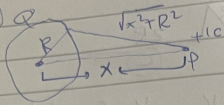
$$= 9 \times 10^9 (0.4393) = 0.395 V$$

Ex 2

$$V = k_e \int_0^L \frac{\lambda(x)}{\sqrt{x^2+a^2}} dx$$



13



$$V = \int \frac{k dq}{\sqrt{x^2 + R^2}} = \frac{kQ}{\sqrt{R^2 + x^2}}$$

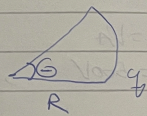
$$V_{x=2R} - V_{x=0} = \frac{kQ}{\sqrt{5}R} - \frac{kQ}{R}$$

$$= \frac{kQ}{R} \left(\frac{1}{\sqrt{5}} - 1 \right)$$

14

$$S = R \sin \theta$$

$$L = \frac{q}{R \sin \theta}$$



$$V_{ARC} = \int \frac{dq}{R}$$

$$V_{ARC} = \frac{kQ}{R}$$

$$E_{ARC} = \frac{2L \sin(\frac{\theta}{2})}{R}$$

$$L = S = \frac{2\pi R}{2} = R\pi = 0,14$$

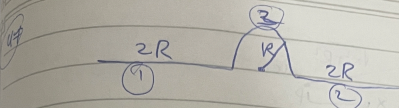
$$R = \frac{0,14}{\pi}$$

$$L = 11 \text{ cm}, q = 7,5 \mu\text{C}$$

$$V = \frac{9 \times 10^9 \times 7,5 \times 10^{-6}}{\frac{0,14}{\pi}}$$

bent





$$V = V_1 + V_2 + V_3$$

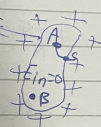
$$V_{\text{red}} = k_e k \ln \left| \frac{L+q}{q} \right|$$

$$= 2k_e k \ln \left| \frac{2R+R}{R} \right| + \frac{\ln 2}{R} \quad , \quad d = \frac{Q}{\pi R}$$

[50]

spherical conducting shell

$$\Delta V = V_A - V_B = - \int_A^B \vec{E} \cdot d\vec{r} = 0$$



$$V_B = V_A$$

$$V_B = 500V \quad , \quad V_A = 500 \quad , \quad V_B = 500$$

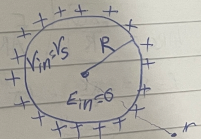
$$\text{Ex : } R = 14 \text{ cm}$$

$$Q = 26 \text{ nC}$$

$$E = \frac{k_e q}{r^2}$$

$$V_P = \frac{k_e q}{r}$$

$$\sigma = \frac{Q}{4\pi R^2}$$



Sigma

$$\textcircled{a} E|_{r=10\text{cm}} = \text{Zero}$$

$$V|_{r=10} = \frac{kqQ}{R} = \frac{9 \times 10^9 \times 26 \times 10^{-6}}{0.14} \rightarrow \text{نفس } R \text{ المسافة}$$

لذلك يكون الجهد واحد

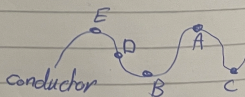
$$\textcircled{b} E|_{r=20} = \frac{kqQ}{R^2} = \frac{9 \times 10^9 \times 26 \times 10^{-6}}{0.2^2}$$

$$V|_{r=20} = \frac{kqQ}{r} = \frac{9 \times 10^9 \times 26 \times 10^{-6}}{0.2}$$

$$\textcircled{c} E|_{r=14} = \frac{kqQ}{R^2} = \frac{Q}{66}$$

$$V|_{r=14} = \frac{kqQ}{R} = \frac{V}{5}$$

Rank the electric potential from smallest to greatest?



$$V_A = V_B = V_C = V_D = V_E$$