

## Question 24.11

Water has strong solubility, so it may erode the metal plate. Also, it's hard to keep water pure. Impure water can conduct current since it contains ions.

## Question 24.21

I think the electric field will decrease.

The oil's dielectric constant  $\kappa$  is bigger than 1, so the charge will be separate partially in the oil, thus causing the decrease in electric field.

Since  $E = \frac{F}{q}$ , we can measure the force a certain charge have in the electric field.

## Question 25.11

(a) For a resistor  $P = UI = \frac{U^2}{R}$ . when  $T \uparrow$ ,  $R \uparrow$ , since  $U$  is constant, we can found that  $P$  decrease.

(b) For carbon. when  $T \uparrow$ ,  $R \uparrow$ , also  $UI$  is constant, so, we can found that  $P$  increase.

## Question 25.16

The light bulb in A will be much brighter. Since an ideal ammeter contain only a little resistor while an ideal voltmeter has large resistor. So the bulb in (A) has larger current, thus brighter.

## Problem 24.66

(a) This one is equal to these capacitors.

$$C_2(\text{Air}) = \epsilon_0 \frac{A}{d} = (8.85 \times 10^{-12} \text{ F/m}) \times \frac{(\frac{12}{100}) \times (\frac{1}{2} \times \frac{12}{100}) \text{ m}^2}{\frac{4.5}{10000} \text{ m}} \quad \text{C}_2$$

$$= 1.416 \times 10^{-11} \text{ F}$$

$$C = \kappa \cdot \epsilon_0 \frac{A}{d} = \kappa \cdot C_2 = (3.40) \times (1.416 \times 10^{-11} \text{ F}) = 4.8144 \times 10^{-11} \text{ F}$$

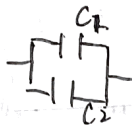
$$C = C_1 + C_2 = 1.416 \times 10^{-11} \text{ F} + 4.8144 \times 10^{-11} \text{ F} = 6.23 \times 10^{-11} \text{ F}$$

(b)  $U = \frac{1}{2} CV^2 = \frac{1}{2} \times (6.23 \times 10^{-11} \text{ F}) \times (18 \text{ V})^2 = 1.01 \times 10^{-8} \text{ J}$

(c)  $\frac{1}{\frac{1}{C_1} + \frac{1}{C_2}} = C = C_1 + C_2 = 2 \times 1.416 \times 10^{-11} \text{ F} = 2.83 \times 10^{-11} \text{ F}$

$$U = \frac{1}{2} CV^2 = \frac{1}{2} \times (2.83 \times 10^{-11} \text{ F}) \times (18 \text{ V})^2 = 4.58 \times 10^{-9} \text{ J}$$

Question 24.71.

(a)  $C = C_1 + C_2$    $C_1 = \epsilon_0 \frac{A}{d} = \epsilon_0 x \frac{L(L-x)}{D}$   $C_2 = K \cdot \epsilon_0 \cdot \frac{A'}{d} = K \cdot \epsilon_0 \cdot \frac{Lx}{D}$

$$C = C_1 + C_2 = \epsilon_0 \frac{L(L-x) + KxL}{D} = \frac{\epsilon_0 L}{D} (L + (K-1)x)$$

(b)  $U = \frac{1}{2} CV^2 \Rightarrow U' = \frac{1}{2} V^2 C dx = \frac{1}{2} V^2 \frac{\epsilon_0 L (K-1)}{D} \Rightarrow \frac{dU}{dx} = \frac{V^2 \epsilon_0 L (K-1)}{2D}$

$$\Rightarrow dU = + \frac{(K-1) \epsilon_0 V^2 L}{2D} dx$$

(c)  $Q = CV = \frac{\epsilon_0 L V}{D} (L + (K-1)x)$

$$U = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} \cdot \frac{\epsilon_0 L V^2}{D} (L + (K-1)x)$$

Also we can find that  $F = - \frac{\epsilon_0 L V^2}{2D} (K-1)$

So that the distance direction is opposite direction of the displacement

So it's repulsive force So energy is negative

$$\Rightarrow -U = \frac{1}{2} V^2 \frac{\epsilon_0 L (K-1)}{D} \Rightarrow dU = - \frac{(K-1) \epsilon_0 V^2 L}{2D} dx$$

(d)  $U = \int F dx \Rightarrow dU = -F dx = - \frac{(K-1) \epsilon_0 V^2 L}{2D} dx$ , the force is in the opposite direction of  $x$  to make  $dU$  positive

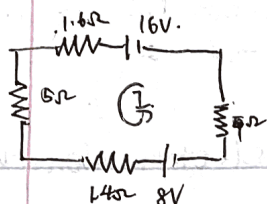
So it's a force pushing it out.

(e) Because when plates connect to the battery, the plate is not isolated. When the work done on the slow by the charges on the plate, energy of battery is also changed. But in part (c) the plate is isolated, the force is of the same distance as Fig. 24.16.

In opposite. in (c)  $F = \frac{(K-1) \epsilon_0 V^2 L}{2D}$ , the force is in the same direction of  $x$

So it's a force pulling it in.

Question 25.33



(a) By applying KCL  
 $8V + I \cdot (5\Omega + 1.6\Omega + 1.6\Omega + 1.6\Omega) = 16V$

$\Rightarrow I = \frac{8}{17} A = 0.47 A$ . And it's counter clockwise

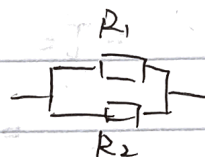
(b)  $V_{ab} = 16V - 1.6\Omega \cdot 0.47A = 15.25V$

Question 25.52

$R_1 = \frac{\rho L}{A} = \frac{\rho x}{A}$

$R_2 = \frac{\rho L'}{A} = \frac{\rho(L-x)}{A}$

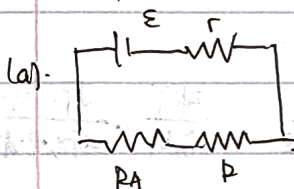
$V = R_1 I_1 = R_2 I_2$



$(2.86A) \times \frac{\rho x}{A} = (1.65A) \times \frac{\rho(L-x)}{A}$

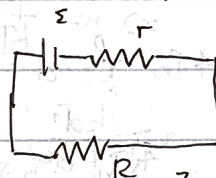
$\Rightarrow 2.86x = 1.65(2000m - x) \Rightarrow x = 731.7m$

Question 25.67



$I_A = \frac{\varepsilon}{r + R_A + R}$

what we want to measure:



$I = \frac{\varepsilon}{r + R}$

$\frac{I}{I_A} = \frac{r + r + R_A}{r + R} = 1 + \frac{R_A}{R + r}$

$R_A$  is smaller,  $\frac{I}{I_A}$  is closer to 1.

so that it's more ideal.

(b)  $I_A = 0.99I \Rightarrow \frac{1}{0.99} \approx 1 + \frac{R_A}{R + r} \Rightarrow R_A = (\frac{1}{0.99} - 1) \times (0.45\Omega + 3.80\Omega) \approx 0.43\Omega$

(c)  $I - I_A = \frac{\varepsilon R_A}{(r + R)(r + R + R_A)} \approx \Delta I \Rightarrow \text{when } R_A \uparrow, \Delta I \uparrow$

if  $R_A$  bigger than  $0.43\Omega$ ,  $\Delta I$  will be bigger

so that  $\frac{\Delta I}{I}$  will be bigger than 1% (in part (b)).



# Essay Question I.

$$\text{Mean free time} = \frac{\text{Mean free path}}{\text{average speed}}$$

$$\lambda = \frac{1}{\sqrt{2} \pi n d^2} \quad (d = \text{diameter of molecule, } n = \text{electron density})$$

$$V_{\text{avg}} = \sqrt{\frac{8RT}{\pi M}} \Rightarrow \tau = \frac{1}{\sqrt{2} \pi n d^2} \cdot \sqrt{\frac{\pi M}{8RT}}$$

$$\Rightarrow \tau = \frac{1}{\sqrt{2} \times 3.14 \times 8.5 \times 10^{28} \times (2.28 \times 10^{-10})^2} \times \sqrt{\frac{9.1 \times 10^{-31} \times 3.14}{8.314 \times 8 \times 237}}$$

$$= 6.39 \times 10^{-28} \text{ s}$$

in the sound:  $v = \sqrt{\frac{5kT}{3m_e}} \Rightarrow v^2 = \frac{5kT}{3m_e}$

$$P = nkT \Rightarrow n = \frac{P}{kT}$$

$$\Rightarrow \tau = \frac{1}{\sqrt{2} \cdot \frac{P}{kT} \cdot d^2} \cdot \sqrt{\frac{M}{RT}} = \frac{kT \cdot \sqrt{M}}{4\sqrt{2} \cdot P \cdot d^2 \cdot \sqrt{R}} = \frac{5kT}{3M} \cdot \frac{\sqrt{M} \cdot M \cdot 3}{4\sqrt{2} \cdot P \cdot d^2 \cdot \sqrt{R} \cdot \sqrt{5}}$$

$$= v_{\text{sound}}^2 \cdot \frac{1.54 \times 10^{-48}}{P d^2}$$

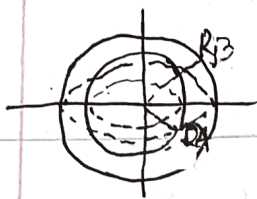
$$t_{\text{mean}} = \frac{V}{4\sqrt{2} \pi^2 N \cdot v} = \frac{1}{4\sqrt{2} \pi^2 \cdot \sqrt{\frac{3kT}{m_e}} \cdot 8.47 \times 10^{26} \text{ m}^{-3}} = 7.6 \times 10^{-15} \text{ s}$$

$$v_{\text{sound}} = \sqrt{\frac{3kT}{m_e}} \cdot \sqrt{\frac{5}{9}}$$

$$\Rightarrow t_{\text{mean}} = \frac{0.063}{v_{\text{sound}}}$$

Essay question 2. (find the capacity per area for RA)

① concentric sphere.



$$E = k \cdot \frac{q}{R_+^2} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{R_+^2}$$

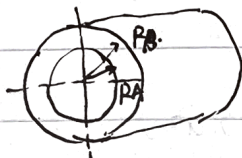
$$\Delta V = \int_{RA}^{RB} E dr = \frac{q}{4\pi\epsilon_0} \int_{RA}^{RB} \frac{dr}{r^2} = \frac{q}{4\pi\epsilon_0} \left( \frac{1}{RA} - \frac{1}{RB} \right)$$

$$C = \frac{q}{V} = 4\pi\epsilon_0 \cdot \left( \frac{RA \cdot RB}{d} \right)$$

capacity per unit area:

$$\frac{C}{A} = \frac{\epsilon_0}{d} + \frac{\epsilon_0}{RB}$$

② concentric cylinders.



$$E = \oint \vec{E} d\vec{A} = E \cdot 2\pi r \cdot L = \frac{q_{enc}}{\epsilon_0} = \frac{q}{\epsilon_0}$$

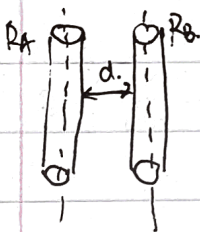
$$\Rightarrow E = \frac{q}{2\pi\epsilon_0 \cdot r \cdot L}$$

$$V = \int_{RA}^{RB} \frac{q}{2\pi\epsilon_0 \cdot L} \frac{dr}{r} = \frac{q}{2\pi\epsilon_0 \cdot L} \int_{RA}^{RB} \frac{dr}{r} = \frac{q}{2\pi\epsilon_0 \cdot L} \cdot \ln\left(\frac{RB}{RA}\right)$$

$$\Rightarrow C = \frac{q}{V} = \frac{2\pi\epsilon_0 L}{\ln\left(\frac{RB}{RA}\right)}$$

$$\frac{C}{A} = \frac{\epsilon_0}{RA \cdot \ln\left(\frac{RB}{RA}\right)}$$

③ Parallel cylinders:



$$V = - \int_{RA}^{RB} E dr$$

$$E = \frac{q}{2\pi\epsilon_0 r L} + \frac{q}{2\pi\epsilon_0 r L}$$

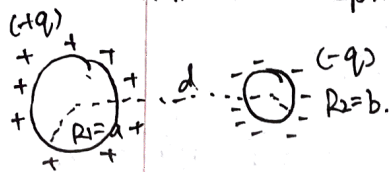
$$\Rightarrow V = \frac{q}{2\pi\epsilon_0 L} \ln\left(1 + \frac{d}{RA}\right) \Rightarrow C = \frac{q}{V} = \frac{2\pi\epsilon_0 L}{\ln\left(1 + \frac{d}{RA}\right)}$$

$$\Rightarrow \frac{C}{A} = \frac{\epsilon_0}{RA \cdot \ln\left(1 + \frac{d}{RA}\right)}$$

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④. Two concentric spheres.



$$\vec{E} = \vec{E}_A + \vec{E}_B = \frac{q}{4\pi\epsilon_0 r^2} + \frac{q}{4\pi\epsilon_0 (d-r)^2}$$

$$- \int_{V_A}^{V_B} dV = \frac{q}{4\pi\epsilon_0} \int_a^{d+a} \left( \frac{1}{r^2} + \frac{1}{(d-r)^2} \right) dr$$

$$= \frac{q}{4\pi\epsilon_0} \left[ -\frac{1}{a} - \frac{1}{d+a} \right]$$

$$= \frac{q}{4\pi\epsilon_0 a} - \frac{1}{4\pi\epsilon_0 (d+a)}$$

$$C = \frac{q}{V} = - \frac{2\pi\epsilon_0 R_1^2}{d}$$

$$\frac{C}{A} = \frac{\epsilon_0}{2d} + \frac{\epsilon_0}{2R_1}$$

$$+ 2\pi\epsilon_0 R_1$$

⑤ Parallel Plate.

$$E = \frac{q}{A\epsilon_0}$$

$$\int_0^d \vec{E} \cdot d\vec{r} = \frac{qd}{A\epsilon_0}$$

$$C = \frac{q}{V} = \frac{A\epsilon_0}{d} \Rightarrow \frac{C}{A} = \frac{\epsilon_0}{d}$$

$$= \int_0^d \frac{q}{A\epsilon_0} =$$

Capacity per area for "A" object

$$\textcircled{1} \frac{\epsilon_0}{d} + \frac{\epsilon_0}{R_1}$$

$$\textcircled{2} \frac{\epsilon_0}{R_1 \ln(\frac{R_2}{R_1})}$$

$$\textcircled{3} \frac{\epsilon_0}{R_1 \ln(1 + \frac{d}{R_1})}$$

$$\textcircled{4} \frac{\epsilon_0}{2d} + \frac{\epsilon_0}{2R_1}$$

$$\textcircled{5} \frac{\epsilon_0}{d}$$

① have the greatest capacity per unit area.