Homework - chapter 21 [7, 13, 19, 29, 35, 43, 49, 57, 63]

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Q7 $F \propto \frac{1}{r^2}$, if the force is tripled, the distance has been reduced by a factor of $\sqrt{3}$.

$$r = \frac{r_0}{\sqrt{3}} = \frac{8.45\text{cm}}{\sqrt{3}} = \boxed{4.88\text{cm}}$$

Q13 $$F_{12} = \frac{k|Q_1Q_2|}{d^2} = \frac{(8.988\times10^9 N.m^2/C^2)(7.0\times10^{-6}C)(8.0\times10^{-6}C)}{(1.20m)^2}$$

$$= \boxed{0.3495N}$$

$$F_{13} = \frac{k|Q_1Q_3|}{d^2} = \frac{(8.988\times10^9 N.m^2/C^2)(7.0\times10^{-6}C)(6.0\times10^{-6}C)}{(1.20m)^2}$$

$$= \boxed{0.2622N}$$

$$F_{23} = \frac{k|Q_2Q_3|}{d^2} = \frac{(8.988\times10^9 N.m^2/C^2)(8.0\times10^{-6}C)(6.0\times10^{-6}C)}{(1.20m)^2}$$

$$= \boxed{0.2996N = F_{32}}$$

Now, calculate Net Force

$$F_{1x} = F_{12x} + F_{13x} = -(0.3495N)\cos60^\circ + (0.2622N)\cos60^\circ$$
$$= -4.365\times10^{-2}N$$

$$F_{1y} = F_{12y} + F_{13y} = -(0.3495N)\sin60^\circ - (0.2622N)\sin60^\circ$$
$$= -5.297\times10^{-1}N$$

$$F_1 = \sqrt{F_{1x}^2 + F_{1y}^2} = \boxed{0.53N}$$

$$\theta_1 = \tan^{-1}\frac{F_{1y}}{F_{1x}} = \tan^{-1}\frac{-5.297\times10^{-1}N}{-4.365\times10^{-2}N} = \boxed{265^\circ}$$

$F_{2x} = F_{21x} + F_{23x} = (0.3495N)\cos 60° - (0.2996N)$

$= -1.249 \times 10^{-1} N$

$F_{2y} = F_{21y} + F_{23y} = (0.3495N)\sin 60° + 0 = 3.027 \times 10^{-1} N$

$F_2 = \sqrt{F_{2x}^2 + F_{2y}^2} = \boxed{0.33N}$

$\theta_2 = \tan^{-1} \frac{F_{2y}}{F_{2x}} = \tan^{-1} \frac{3.027 \times 10^{-1} N}{-1.249 \times 10^{-1} N} = \boxed{112°}$

$F_{3x} = F_{31x} + F_{32x} = -(0.2622N)\cos 60° + (0.2996N)$

$= 1.685 \times 10^{-1} N$

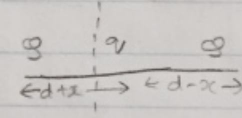
$F_{3y} = F_{31y} + F_{32y} = (0.2622N)\sin 60° + 0$

$= 2.271 \times 10^{-1} N$

$F_3 = \sqrt{F_{3x}^2 + F_{3y}^2} = \boxed{0.26N}$

$\theta_3 = \tan^{-1} \frac{F_{3y}}{F_{3x}} = \tan^{-1} \frac{2.271 \times 10^{-1} N}{1.685 \times 10^{-1} N} = \boxed{53°}$

19] a] $\frac{Qq}{4\pi\epsilon_0 (d-x)^2}$ to the left



& a lesser force of $\frac{Qq}{4\pi\epsilon_0 (d+x)^2}$ to the right

the net force is at origin.

$F_{net} = \frac{Qq}{4\pi\epsilon_0 (d+x)^2} - \frac{Qq}{4\pi\epsilon (d-x)^2} = \frac{Qq}{4\pi\epsilon_0 (d+x)^2 (d-x)^2} \cdot [(d-x)^2 - (d+x)^2]$

$= \frac{-4Qqd}{4\pi\epsilon_0 (d+x)^2 (d-x)^2} x = \frac{-Qqd}{\pi\epsilon_0 (d+x)^2 (d-x)^2} x$

we assume that $x \ll d$

$$F_{net} = \frac{-Qqd}{\pi\epsilon_0 (d+x)^2 (d-x)^2} x \approx -\frac{Qq}{\pi\epsilon_0 d^3} x$$

simple harmonic oscillator $k_{elastic} = \frac{Qq}{\pi\epsilon_0 d^3}$

Spring constant

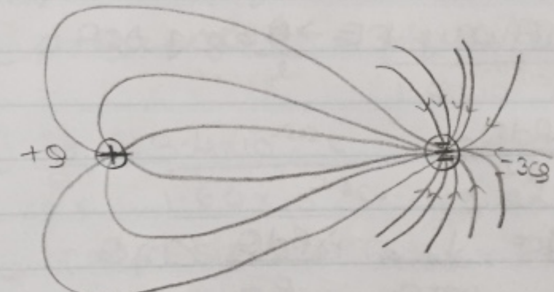
$$T = 2\pi\sqrt{\frac{m}{k_{elastic}}} = 2\pi\sqrt{\frac{m}{\frac{Qq}{\pi\epsilon_0 d^3}}} = \boxed{2\pi\sqrt{\frac{m\pi\epsilon_0 d^3}{Qq}}}$$

5] Sodium, atomic mass = 23

$$T = 2\pi\sqrt{\frac{m\pi\epsilon_0 d^3}{Qq}} = 2\pi\sqrt{\frac{(29)(1.66\times10^{-23})\pi(8.85\times10^{-2}C^2/N\cdot m^2)(3\times10^{-10}m)^3}{(1.60\times10^{-19}C)^2}}$$

$$= 2.4\times10^{-13}\,s\left(\frac{10^{12}\,ps}{1\,s}\right) = \boxed{0.24\,ps \approx 0.2\,ps}$$

29]



35] rightward direction to be positive

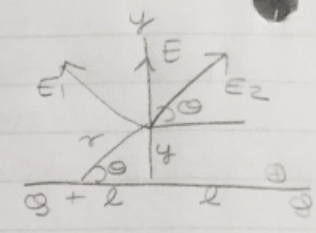
field +Q is positive & -Q is negative.

$$E = k\frac{Q}{(x+a)^2} - k\frac{Q}{(x-a)^2} = kQ\left(\frac{1}{(x+a)^2} - \frac{1}{(x-a)^2}\right)$$

$$= \boxed{\frac{-4kQxa}{(x^2-a^2)^2}}$$

negative sign field point to the $\boxed{\text{left}}$

43] a] $\vec{E} = 2 \dfrac{Q}{4\pi\epsilon_0(l^2+y^2)} \sin\theta$



$\vec{y} = \dfrac{Qy}{2\pi\epsilon_0(l^2+y^2)^{3/2}} \hat{j}$

b] $E = \dfrac{Qy}{2\pi\epsilon_0(l^2+y^2)^{3/2}} \rightarrow$

$\dfrac{dE}{dy} = \dfrac{Q}{2\pi\epsilon_0(l^2+y^2)^{3/2}} + \left(\dfrac{-3}{2}\right) \dfrac{Qy}{2\pi\epsilon_0(l^2+y^2)^{5/2}} (2y)$

$= 0 \rightarrow \dfrac{1}{(l^2+y^2)^{3/2}} = \dfrac{3y^2}{(l^2+y^2)^{5/2}} \rightarrow y^2 = \dfrac{1}{2} l^2$

$\boxed{y = \pm l/\sqrt{2}}$

So, maximum because magnitude is positive. field is 0 midway & $E \rightarrow 0$ as $y \rightarrow \infty$

49] $dE = \dfrac{1}{4\pi\epsilon_0} \dfrac{\lambda R d\theta}{R^2}$

dE horizontal $= \dfrac{1}{4\pi\epsilon_0} \dfrac{\lambda R d\theta}{R^2} \cos\theta$

E horizontal $= \displaystyle\int_{-\theta_0}^{\theta_0} \dfrac{1}{4\pi\epsilon_0} \cos\theta \dfrac{\lambda R d\theta}{R^2} = \dfrac{\lambda}{4\pi\epsilon_0 R}$

$\displaystyle\int_{-\theta_0}^{\theta_0} \cos\theta d\theta = \dfrac{\lambda}{4\pi\epsilon_0 R} [\sin\theta_0 - \sin(-\theta)_0] \Rightarrow \dfrac{2\lambda\sin\theta}{4\pi\epsilon_0 R}$

negative x direction, so $E = \boxed{\dfrac{-2\lambda\sin\theta_0}{4\pi\epsilon_0 R} \hat{i}}$

57] a] Acceleration is produced by the electric force

$\vec{F}_{net} = m\vec{a} = q\vec{E} = e\vec{E} \rightarrow$

$\vec{a} = \frac{-e}{m}\vec{E} = \frac{-(1.60\times10^{-19}C)}{(9.11\times10^{-31}Kg)}[(2.0\hat{i}+8.0\hat{j})\times10^{4}N/C]$

$= (-3.513\times10^{15}\hat{i} - 1.405\times10^{16}\hat{j})m/s^2$

$\approx \boxed{-3.5\times10^{15}m/s^2\,\hat{i} - 1.4\times10^{16}m/s^2\,\hat{j}}$

b] $\vec{v} = \vec{v} + \vec{a}t = (8.0\times10^{4}m/s)\hat{j} + [(-3.513\times10^{15}\hat{i} - 1.405\times10^{16}\hat{j})m/s^2](1.0\times10^{-9}s)$

$= (-3.513\times10^{6}\hat{i} - 1.397\times10^{7}\hat{j})m/s.$

$\tan^{-1}\frac{v_y}{v_x}$ $\tan^{-1}\left(\frac{-1.397\times10^{7}m/s}{-3.513\times10^{6}m/s}\right) = 256°$ or $-104°$

This is the direction to x axis.

$\boxed{\theta = 106° \text{ counter clockwise}}$

63] a] $p = ql \rightarrow q = \frac{p}{l} = \frac{3.4\times10^{-30}C\cdot m}{1.0\times10^{-10}m} = \boxed{3.4\times10^{-20}C}$

b] $\frac{q}{e} = \frac{3.4\times10^{-20}C}{1.60\times10^{-19}C} = 0.21$ so $\boxed{\text{No}}$ net charge on each atom is not an integer!

c] $\tau = pE\sin\theta \rightarrow \tau_{max} = pE = (3.4\times10^{-30}C\cdot m)(2.5\times10^{4}N/C) = \boxed{8.5\times10^{-26}N\cdot m}$

d] $W = \Delta U = (-pE\cos\theta\text{ final}) - (-pE\cos\theta\text{ initial})$

$= pE(\cos\theta\text{ initial} - \cos\theta\text{ final})$

$= (3.4\times10^{-30}C\cdot m)(2.5\times10^{4}N/C)[1-\cos45°]$

$= \boxed{2.5\times10^{-26}J}$

Homework - chapter 22 [3, 7, 17, 29, 43]
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Q3] a] Since the field, no lines originates or terminate inside the cube so the net flux is $\Phi_{net} = \boxed{0}$

b] Two opposite faces with field line perpendicular to the faces. other 4 faces have field lines parallel to those faces Thus $\Phi_{parallel} = \boxed{0}$ of the 2 faces that are perpendicular to the field ones, there's an angle between field lines & face area vector is $180°$. with vector is $0°$

Thus we have $\Phi_{entering} = \vec{E} \cdot \vec{A} = E_0 A \cos 180°$ $= -E_0 l^2$ & $\Phi_{leaving} = \vec{E} \cdot \vec{A} = E_0 A \cos 0° = \boxed{E_0 l^2}$

Q7] a] Guess law,

$$\Phi_E = \frac{Q_{encl}}{\epsilon_0} = \frac{-1.0 \times 10^{-6} C}{8.85 \times 10^{-12} C^2/N \cdot m^2} = \boxed{-1.1 \times 10^5 \, N \cdot m^2/C}$$

b] Since there is no charge enclosed by surface A_2, $\Phi_E = \boxed{0}$

Q17] $\oint \vec{E} \cdot d\vec{A} = E(4\pi r^2) = \frac{Q_{encl}}{\epsilon_0} \rightarrow E = \frac{1}{4\pi\epsilon_0} \frac{Q_{encl}}{r^2}$

let $r_1 = 6.0 cm$ & $r_2 = 12.0 cm$.

a] Negative charge is enclosed for $r < r_1$

$$E = \frac{1}{4\pi\epsilon_0}\frac{Q_{encl}}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{\rho(-)\left(\frac{4}{3}\pi r^3\right)}{r^2} = \frac{\rho(-) r}{3\epsilon_0}$$

$$= \frac{(-5.0\,C/m^3) r}{3(8.85\times10^{-12}\,C^2/N\cdot m^2)} = \boxed{(-1.9\times10^{11}\,N/C\cdot m) r}$$

b] $r_1 < r < r_2$

$$E = \frac{1}{4\pi\epsilon_0}\frac{Q_{encl}}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{\rho(-)\left(\frac{4}{3}\pi r_1^3\right) + \rho(+)\left[\frac{4}{3}\pi(r^3 - r_1^3)\right]}{r^2}$$

$$= \frac{(\rho(-) - \rho(+))(r_1^3)}{3\epsilon_0 r^2} + \frac{\rho(+) r}{3\epsilon_0}$$

$$= \frac{[(-5.0\,C/m^3) - (8.0\,C/m^3)](0.060\,m)^3}{3(8.85\times10^{-12}\,C^2/N\cdot m^2) r^2} + \frac{(8.0\,C/m^3) r}{3(8.85\times10^{-12}\,C^2/N\cdot m^2)}$$

$$= \boxed{\frac{(-1.1\times10^{8}\,N\cdot m^2/C)}{r^2} + (3.0\times10^{11}\,N/C\cdot m) r}$$

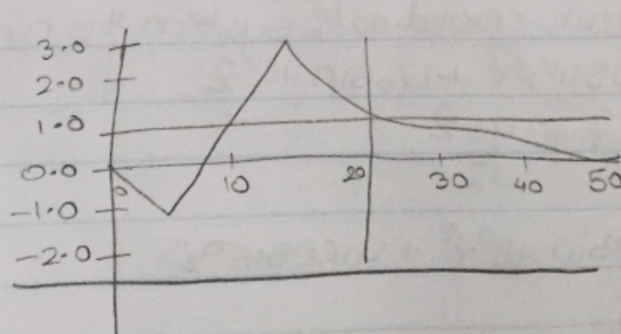
c] $r_2 < r$

$$E = \frac{1}{4\pi\epsilon_0}\frac{Q_{encl}}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{\rho(-)\left(\frac{4}{3}\pi r_1^3\right) + \rho(+)\left[\frac{4}{3}\pi(r_2^3 - r_1^3)\right]}{r^2}$$

$$= \frac{[(-5.0\,C/m^3) - (8.0\,C/m^3)](0.060\,m)^3 + (8.0\,C/m^3)(0.120\,m)^3}{3(8.85\times10^{-12}\,C^2/N\cdot m^2) r^2}$$

$$= \boxed{\frac{4.1\times10^{8}\,N\cdot m^2/C}{r^2}}$$

d]



29] Gauss's law

$$\oint \vec{E} \cdot d\vec{A} = E(4\pi r^2) = \frac{q_{encl}}{\epsilon_0} \rightarrow E = \frac{q_{encl}}{4\pi\epsilon_0 r^2}$$

a] $0 < r < r_1$ $\quad E = \frac{q_{encl}}{4\pi\epsilon_0 r^2} = \boxed{0}$

b] $r_1 < r < r_0$ $\quad \rho = \frac{Q}{(4/3\pi r_0^3 - 4/3\pi r_1^3)} = \frac{3Q}{4\pi(r_0^3 - r_1^3)}$

$$E = \frac{q_{encl}}{4\pi\epsilon_0 r^2} = \frac{\rho V_{encl}}{4\pi\epsilon_0 r^2} = \frac{\frac{3Q}{4\pi(r_0^3 - r_1^3)}\left[4/3\pi r^3 - 4/3\pi r_1^3\right]}{4\pi\epsilon_0 r^2}$$

$$\boxed{= \frac{Q}{4\pi\epsilon_0 r^2} \frac{(r^3 - r_1^3)}{(r_0^3 - r_1^3)}}$$

c] $r > r_0$ $\quad E = \frac{Q}{4\pi\epsilon_0 r^2}$

43] a] $\oint \vec{E} \cdot d\vec{A} = 2EA$

charge density of slab multiplied by the volume of the slab. $q_{enc} = \rho_E(Ad)$

Gauss's law $\oint \vec{E} \cdot d\vec{A} = 2EA = \frac{\rho_E A d}{\epsilon_0} \rightarrow E = \boxed{\frac{\rho_E d}{2\epsilon_0}}$

It's independent.

b] axes parallel $(\hat{z})$ & perpendicular $(\hat{r})$ to the slab. The new coordinate system the axis $45°$

$$\vec{r_0} = y_0 \cos 45° \hat{r} + y_0 \sin 45° \hat{z}$$

$$= \frac{y_0}{\sqrt{2}} \hat{r} + \frac{y_0}{\sqrt{2}} \hat{z}.$$

$$\vec{V_0} = -V_0 \sin 45° \hat{r} + V_0 \cos 45° \hat{z}$$

$$= \frac{-v_0}{\sqrt{2}}\hat{r} + \frac{v_0}{\sqrt{2}}\hat{z}$$

$$\vec{a} = qE/m\hat{r}$$

The perpendicular components are the insured.

$$0 = v_{r0}^2 - 2a(r - r_0) = \frac{v_0^2}{2} - 2\frac{q}{m}\left(\frac{\rho E d}{2\epsilon_0}\right)\left(\frac{y_0}{\sqrt{2}} - 0\right)$$

This will give the minimum speed that the particle can have to reach the slab.

$$v_0 \geq \boxed{\sqrt{\frac{\sqrt{2}q\rho_E d y_0}{m\epsilon_0}}}$$

✓

Homework - chapter 23 [11, 19, 23, 27, 31, 37, 41, 45, 51, 57]

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Q11] a] $\boxed{V_{BA} = 0}$. The distance between 2 points is exactly perpendicular to the field lines.

b] $V_{CB} = V_C - V_B = (-4.20 N/C)(7.00 m) = \boxed{-29.4 V}$

c] $V_{CA} = V_C - V_A = V_C - V_B + V_B - V_A = V_{CB} + V_{BA}$
$= -29.4 V + 0 = \boxed{-29.4 V}$

Q19] a] $E(r \geq r_0) = \dfrac{Q}{4\pi\epsilon_0 r^2}$; $V(r > r_0)$

$$= -\int_{\infty}^{r} \frac{Q}{4\pi\epsilon_0 r^2}\, dr = \frac{Q}{4\pi\epsilon_0 r}\Bigg|_{\infty}^{r} = \boxed{\frac{Q}{4\pi\epsilon_0 r}}$$

b] $4\pi r^2 E = \dfrac{Q\, 4/3\pi r^3}{\epsilon_0\, 4/3\pi r_0^3} \longrightarrow E(r < r_0) = \dfrac{Qr}{4\pi\epsilon_0 r_0^3}$.

field from surface $r < r_0$

$$V(r < r_0) - V(r_0) - \int_{r_0}^{r} \frac{Qr}{4\pi\epsilon_0 r_0^3}\, dr = \frac{Q}{4\pi\epsilon_0 r_0} - \frac{Qr^2}{8\pi\epsilon_0 r_0^3}$$

$$\Bigg|_{r_0}^{r} = \boxed{\frac{Q}{8\pi\epsilon_0 r_0}\left(3 - \frac{r^2}{r_0^2}\right)}$$

c] To plot calculate $V_0 = V(r = r_0) = \dfrac{Q}{4\pi\epsilon_0 r_0}$ &

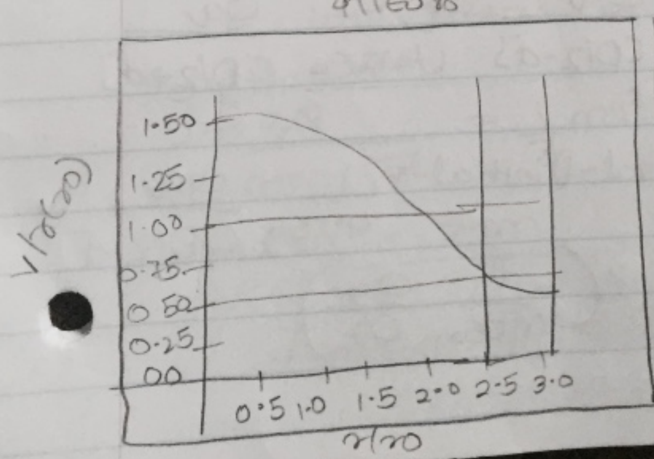
$$E_0 = E(r = r_0) = \frac{Q}{4\pi\epsilon_0 r_0^2}$$

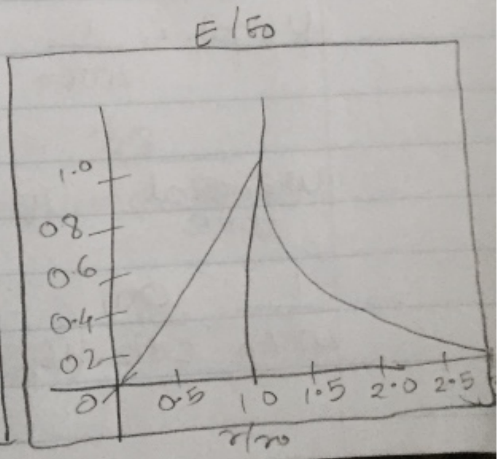
for $r < r_0$: $$V/V_0 = \frac{\frac{Q}{8\pi\epsilon_0 r_0}\left(3 - \frac{r^2}{r_0^2}\right)}{\frac{Q}{4\pi\epsilon_0 r_0}}$$

$$= \frac{1}{2}\left(3 - \frac{r^2}{r_0^2}\right), \quad E/E_0 = \frac{\frac{Qr}{4\pi\epsilon_0 r_0^3}}{\frac{Q}{4\pi\epsilon_0 r_0^2}} = \frac{r}{r_0}$$

for $r > r_0$: $$V/V_0 = \frac{\frac{Q}{4\pi\epsilon_0 r}}{\frac{Q}{4\pi\epsilon_0 r_0}} = \frac{r_0}{r} = (r/r_0)^{-1}$$

$$E/E_0 = \frac{\frac{Q}{4\pi\epsilon_0 r^2}}{\frac{Q}{4\pi\epsilon_0 r_0^2}} = \frac{r_0^2}{r^2} = (r/r_0)^{-2}$$





23] The field inside the cylinder is 0, & the field outside cylinder is $\frac{\sigma R_0}{\epsilon_0 R}$

a] $V_R - V_{R_0} = -\int_{R_0}^{R} \vec{E}\cdot d\vec{l} = -\int_{R_0}^{R} E\,dR$

$= -\int_{R_0}^{R} \frac{\sigma R_0}{\epsilon_0 R}\,dR = \frac{-\sigma R_0}{\epsilon_0} \ln \frac{R}{R_0} \rightarrow \boxed{V_R = V_0 - \frac{\sigma R_0}{\epsilon_0} \ln \frac{R}{R_0}}$, $R > R_0$

b] electric field inside cylinder is 0, so the potential inside is constant & equal to the potential on the surface $\boxed{V_0}$

c] $\boxed{NO}$, we are not able to assume $V = 0$ @ $R = \infty$

$V \neq 0$ because there would be charge at infinity for cylinder if $R = \infty$, $V_R = -\infty$

27] $U_{initial} = \frac{1}{4\pi\epsilon_0} \frac{Qq}{D/2} + \frac{1}{4\pi\epsilon_0} \frac{Qq}{D/2}$

$U_{final} = \frac{1}{4\pi\epsilon_0} \frac{Qq}{[D/2-d]} + \frac{1}{4\pi\epsilon_0} \frac{Qq}{[D/2+d]}$

$W_{external\ force} = U_{final} - U_{initial} = \frac{1}{4\pi\epsilon_0} \frac{Qq}{[D/2-d]} +$

$\frac{1}{4\pi\epsilon_0} \frac{Qq}{[d/2+d]} - 2\left(\frac{1}{4\pi\epsilon_0} \frac{Qq}{D/2}\right)$

$$= \frac{2Qq}{4\pi\epsilon_0}\left[\frac{1}{[0-2d]} + \frac{1}{[0+2d]} - \frac{1}{d/2}\right]$$

$$= 2(8.99\times10^9\,N\cdot m^2/C^2)(25\times10^{-6}C)(0.18\times10^{-6}C)$$

$$\left[\frac{1}{0.040m} + \frac{1}{0.080m} - \frac{1}{0.030m}\right] = \boxed{0.34J}$$

31] $E_{initial} = E_{final} \rightarrow U_{initial} = K_{final} \rightarrow \frac{(-e)(Q)}{4\pi\epsilon_0 r}$

$$= \frac{1}{2}mv^2 \rightarrow v = \sqrt{\frac{2(-e)(Q)}{(4\pi\epsilon_0)mr}}$$

$$= \sqrt{\frac{2(8.99\times10^9 N\cdot m^2/C^2)(-1.60\times10^{-19}C)(-1.25\times10^{-10}C)}{(9.11\times10^{-31}kg)(0.425m)}}$$

$$= \boxed{9.64\times10^5 m/s}$$

37] $U = qV = q\int \frac{dq}{4\pi\epsilon_0\sqrt{r^2+x^2}} = \frac{q}{4\pi\epsilon_0\sqrt{r^2+x^2}}$

$$\int dq = \frac{qQ}{4\pi\epsilon_0\sqrt{r^2+x^2}}$$

$$K_0 + U_0 = K + U$$

$$0 + \frac{qQ}{4\pi\epsilon_0\sqrt{r^2}} = \frac{1}{2}mv^2 + \frac{qQ}{4\pi\epsilon_0\sqrt{r^2+x^2}}$$

Solved by $x = 2.0m$.

$$V = \sqrt{\frac{qQ}{2\pi\epsilon_0 m}\left(\frac{1}{r} - \frac{1}{\sqrt{r^2+x^2}}\right)}$$

$$= \sqrt{\frac{(3.0\mu C)(15.0\mu C)}{2\pi(8.85\times10^{-12}C^2/Nm^2)(7.5\times10^{-3}kg)}}\left(\frac{1}{0.12m} - \frac{1}{\sqrt{(0.12m)^2+(2.0m)^2}}\right)$$

$$= \boxed{b9m/s}$$

44] $$V = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r} = \frac{1}{4\pi\varepsilon_0}\int_0^{R_0}\frac{(aR)^2(2\pi R\,dR)}{\sqrt{x^2+R^2}}$$

$$= \frac{a}{2\varepsilon_0}\int_0^{R_0}\frac{R^3dR}{\sqrt{x^2+R^2}}$$

So, $x^2+R^2=u^2 \rightarrow R^2 = u^2-x^2,\ 2RdR = 2udu$

$$V = \frac{a}{2\varepsilon_0}\int_0^{R_0}\frac{R^3dR}{\sqrt{x^2+R^2}} = \frac{a}{2\varepsilon_0}\int_{R=0}^{R=R_0}\frac{(u^2-x^2)u\,du}{u}$$

$$= \frac{a}{2\varepsilon_0}\left[\frac{1}{3}u^3 - ux^2\right]_{R=0}^{R=R_0}$$

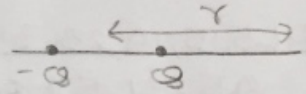
$$= \frac{a}{2\varepsilon_0}\left[\left\{\frac{1}{3}(x^2+R_0^2)\right)^{3/2} - x^2(x^2+R_0^2)^{1/2}\right\} + \frac{2x^3}{3}\Big)$$

$$= \boxed{\frac{a}{6\varepsilon_0}\left[(R_0^2-2x^2)(x^2+R_0^2)^{1/2} + 2x^3\right]}\ x>0$$

45] a] $$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2} =$$

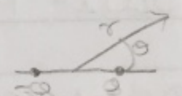
$$\frac{(8.99\times10^9 N.m^2/C^2)(4.8\times10^{-30} C.m)\cos 0}{(4.1\times10^{-9}m)^2}$$

$$= \boxed{2.6\times10^{-3}V}$$



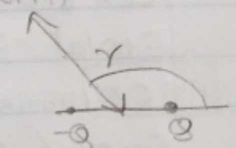
b] $V = \frac{1}{4\pi\epsilon_0}\frac{p\cos\theta}{r^2} = \frac{(8.99\times10^9 N.m^2/C^2)(4.8\times10^{-30} C.m)\cos 45°}{(4.1\times10^{-9} m)^2}$

$= \boxed{1.8\times10^{-3} V}$



c] $V = \frac{1}{4\pi\epsilon_0}\frac{p\cos\theta}{r^2} = \frac{(8.99\times10^9 N.m^2/C^2)(4.8\times10^{-30} C.m)\cos 135°}{(1.1\times10^{-9} m)^2}$

$= \boxed{1.8\times10^{-3} V}$



51] $E_x = -\frac{\partial \lambda}{\partial x} = -2.5y + 3.5yz$; $E_y = -\frac{\partial V}{\partial y}$

$= -2y - 2.5x + 3.5xyz$, $E_z = -\frac{\partial V}{\partial z} = 3.5xy$

$\vec{E} = \boxed{(-2.5y + 3.5yz)\hat{i} + (-2y - 2.5x + 3.5xz)\hat{j} + (3.5xy)\hat{k}}$

57] $U = \frac{1}{4\pi\epsilon_0}\frac{Q_1Q_2}{r} = \frac{-1}{4\pi\epsilon_0}\frac{e^2}{r}$

$\Delta U = U_{final} - U_{initial} = \frac{e^2}{4\pi\epsilon_0}\left(\frac{1}{r_{initial}} - \frac{1}{r_{final}}\right)$

$= (8.99\times10^9 N.m^2/C^2)(1.60\times10^{-19} C)^2 \left(\frac{1}{0.110\times10^{-9} m} - \frac{1}{0.100\times10^{-9} m}\right)\left(\frac{1 eV}{1.60\times10^{-19} J}\right)$

$= -1.31 eV$

Thus, $\boxed{1.3 eV}$ of energy was lost.

Homework - chapter 24 [5, 15, 19, 25, 31, 35, 45, 51, 57, 63]

Jay Patel

Classical Physics - 2 (220)

OL02 - Professor U.

Q5] $Q_{total} = C_1 V_{1\,initial}$ $Q_{1\,final} = C_1 V_{final}$

$Q_{2\,final} = C_2 V_{final}$

$Q_{total} = Q_{1\,final} + Q_{2\,final} = (C_1 + C_2) V_{final} \rightarrow$

$C_1 V_{1\,initial} = (C_1 + C_2) V_{final} \rightarrow$

$C_2 = C_1 \left(\frac{V_{initial}}{V_{final}} - 1 \right) = (7.7 \times 10^{-6} F)\left(\frac{125V}{15V} - 1 \right)$

$= 5.6 \times 10^{-5} F = \boxed{56 \mu F}$

Q15] $Q_{max} = CV_{max} = \epsilon_0 \frac{A}{d} (E_{max} d) = \epsilon_0 A E_{max}$

$= (8.85 \times 10^{-12} F/m)(6.8 \times 10^{-4} m^2)(3.0 \times 10^6 V/m)$

$= \boxed{1.8 \times 10^{-8} C}$

Q19] a] $C = \frac{\epsilon_0 A}{x} \rightarrow x = \frac{\epsilon_0 A}{C}$

$x_{min} = \frac{\epsilon_0 A}{C_{max}} = \frac{(8.85 pF/m)(25 \times 10^{-6} m^2)}{1000.0 \times 10^{-12} F} = 0.22 \mu m$

$x_{max} = \frac{\epsilon_0 A}{C_{min}} = \frac{(8.85 pF/m)(25 \times 10^{-6} m^2)}{1.0 pF}$

$= 0.22 mm = 220 \mu m$

So, $0.22 \mu m \le x \le 220 \mu m$

b] $\Delta x = \frac{dx}{dC}\Delta C = \frac{d}{dC}\left[\frac{\epsilon_0 A}{C}\right]\Delta C = -\frac{\epsilon_0 A}{C^2}\Delta C$

$$\Delta x = \frac{\epsilon_0 A}{\left(\frac{\epsilon_0 A}{x}\right)^2}\Delta C = \frac{x^2 \Delta C}{\epsilon_0 A}$$

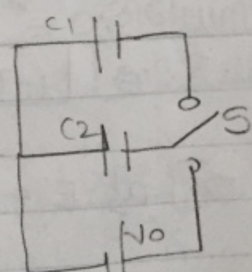
c] $\frac{\Delta x_{min}}{x_{min}} \times 100\% = \frac{x_{min}\Delta C}{\epsilon_0 A} \times 100\%$

$$= \frac{(0.22\,\mu m)(0.1\,pF)(100\%)}{(8.85\,pF/m)(25\,mm^2)} = \boxed{0.01\%}$$

$\frac{\Delta x_{max}}{x_{max}} \times 100\% = \frac{x_{max}\Delta C}{\epsilon_0 A} \times 100\%$

$$= \frac{(0.22\,mm)(0.1\,pF)(100\%)}{(8.85\,pF/m)(25\,mm^2)} = \boxed{10\%}$$

25] $5.0\,\mu F + C = 16\,\mu F \rightarrow C = \boxed{11\,\mu F \text{ connected in parallel}}$
capacitors is parallel added, so in parallel will increase the net capacitors without removing the 5.0 μF capacitor.



31] $Q_2 = C_2 V_0$
When switch will move up, charge from C_2 to C_1
$V = \frac{Q'_2}{C_2} = \frac{Q'_1}{C_1} \rightarrow Q'_2 = Q'_1 \frac{C_2}{C_1}$

$$Q_2 = Q_2' + Q_1' = Q_1' \frac{C_2}{C_1} + Q_1' = Q_1'\left(\frac{C_2+C_1}{C_1}\right)$$

Inserting, the final initial charge

$$Q_1'\left(\frac{C_2+C_1}{C_1}\right) = C_2 V_0 \rightarrow Q_1' \boxed{\frac{C_1 C_2}{C_2+C_1} V_0}$$

$$Q_2' = Q_1' \frac{C_2}{C_1} = \boxed{\frac{C_2^2}{C_2+C} V_0}$$

35] $V_1 = V_2 \rightarrow \frac{Q_1}{C_1} = \frac{Q_2}{C_2}$, $V_3 = V_x \rightarrow \frac{Q_3}{C_3} = \frac{Q_x}{C_x}$.

Since no charge flows through voltmeter

$Q_1 = Q_x$; $Q_2 = Q_3$

Solve for C_x

$$\frac{Q_3}{C_3} = \frac{Q_x}{C_x} \rightarrow C_x = C_3 \frac{Q_x}{Q_3} = C_3 \frac{Q_1}{Q_2}$$

$$= C_3 \frac{C_1}{C_2} = (4.8\mu F)\left(\frac{8.9\mu F}{18.0\mu F}\right) = \boxed{2.4\mu F}$$

45] $C_{net} = C_1 + \frac{C_2 C_3}{C_2+C_3} = C + \frac{C^2}{2C} = \frac{3}{2}C$

$$U = \frac{1}{2} C_{net} V^2 = \frac{3}{4} CV^2 = \frac{3}{4}(22.6\times10^{-6}F)(10.0V)^2$$

$$= \boxed{1.70\times10^{-3} J}$$

51] a] $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$ $r > R$

radius of dr, volume $dV = 4\pi r^2 dr$

energy in the volume $dU = u\,dV$

$$u = \int dU = \int u\,dV = \frac{1}{2}\epsilon_0 \int E^2 dv = \frac{1}{2}\epsilon_0 \int_R^\infty \left(\frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\right)^2$$

$$4\pi r^2 dr = \frac{Q^2}{8\pi\epsilon_0}\int_R^\infty \frac{1}{r^2}dr = \frac{-Q^2}{8\pi\epsilon_0}\left.\frac{1}{r}\right|_R^\infty$$

$$= \boxed{\frac{Q^2}{8\pi\epsilon_0 R}}$$

b] $U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{Q^2}{4\pi\epsilon_0 R} = \boxed{\frac{Q^2}{8\pi\epsilon_0 R}}$

c] $V = \frac{1}{4\pi\epsilon_0}\frac{q}{R}$.

$dw = V\,dq = \frac{1}{4\pi\epsilon_0}\frac{q}{R}dq$, $dU = dw = V\,dq = \frac{1}{4\pi\epsilon_0}\frac{q}{R}dq$

$$U = \int dU = \int dW = \int V\,dq = \int_0^Q \frac{1}{4\pi\epsilon_0}\frac{q}{R}dq$$

$$= \frac{1}{4\pi\epsilon_0 R}\int_0^Q q\,dq = \boxed{\frac{Q^2}{8\pi\epsilon_0 R}}$$

57] $C = K\epsilon_0 \frac{A}{d} \Rightarrow A = \frac{Cd}{K\epsilon_0} = \frac{(35\times10^{-15}F)(2.0\times10^{-9}m)}{(25)(8.85\times10^{-12}C^2/N\cdot m^2)}$

$$= 3.164\times10^{-13}m^2\left(\frac{10^6\,um}{1m}\right)^2 = 0.3164\,um^2 \approx \boxed{0.32\,um^2}$$

Half area,

$$1.5cm^2\left(\frac{10^6\,um}{10^2\,cm}\right)^2\left(\frac{1\text{ bit}}{0.32\,um^2}\right)\left(\frac{1\text{ byte}}{8\text{ bits}}\right)$$

$$\boxed{\begin{array}{l} = 5.86\times10^7\text{ bytes} \\ \approx 59\text{ mbytes}\end{array}}$$

Q3 a] $C = C_1 + C_2 = \epsilon_0 \frac{l(l-x)}{d} + K\epsilon_0 \frac{lx}{d} =$

$$\boxed{\epsilon_0 \frac{l^2}{d}\left[1 + (K-1)\frac{x}{l}\right]}$$

b] Both the capacitors have same potential differences so use $U = \frac{1}{2}CV^2$

$U = \frac{1}{2}(C_1 + C_2)V_0^2 =$

$$\boxed{\epsilon_0 \frac{l^2}{2d}\left[1 + (K-1)\frac{x}{l}\right]V_0^2}$$

c] $dw_{nc} = dU = dU_{cap} + dU_{battery} \rightarrow$

$F_{nc}dx = d\left(\frac{1}{2}CV_0^2\right) + d(Q_{battery}V_0) \rightarrow$

$F_{nc} = \frac{1}{2}V_0^2 \frac{dC}{dx} + V_0 \frac{dQ_{battery}}{dx} = \frac{1}{2}V_0^2 \frac{dC}{dx} -$

$V_0 \frac{dQ_{cap}}{dx} = \frac{1}{2}V_0^2 \frac{dC}{dx} - V_0^2 \frac{dC}{dx} = -\frac{1}{2}V_0^2 \frac{dC}{dx}$

$= -\frac{1}{2}V_0^2 \epsilon_0 \frac{l^2}{d}\left[\frac{(K-1)}{l}\right] = -\frac{V_0^2 \epsilon_0 l}{2d}(K-1)$

So, $\boxed{\frac{V_0^2 \epsilon_0 l}{2d}(K-1), \text{left}}$ because that

this force is in the opposite direction of dx & so is to the right. The magnitude & direction of this attraction force.

Homework - chapter 25 [5, 15, 21, 27, 35, 43, 47, 55, 59]

Jay Patel
classical Physics - 2 (220)
OL02 - Professor U.

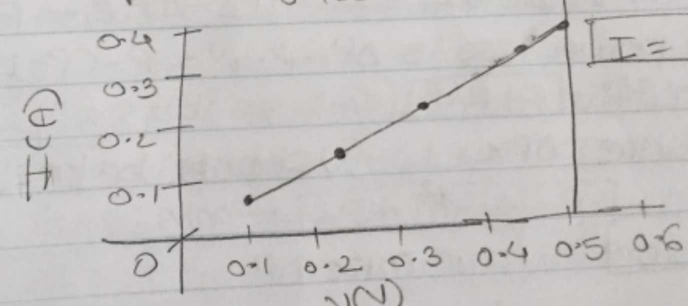
Q5] a] $V = IR \rightarrow I = \frac{V}{R} = \frac{240V}{8.6\Omega} = 27.91A \approx \boxed{28A}$

b] $I = \frac{\Delta Q}{\Delta t} \rightarrow \Delta Q = I\Delta t = (27.91A)(50min)(60s/min) = \boxed{8.4\times10^{4}C}$

Q15] a] If wire obeys ohm's law $V = IR$ or $I = \frac{1}{R}V$
It should have a straight line with a slope of $\frac{1}{R}$ & a y intercept of 0.

b] $Slope = \frac{1}{R} \rightarrow R = \frac{1}{0.720}\ A/V = \boxed{1.39\Omega}$

$\boxed{I = 0.720V}$



c] $R = \rho\frac{l}{A} \rightarrow \rho = \frac{AR}{l} = \frac{\pi d^2 R}{4l}$

$= \frac{\pi(3.2\times10^{-4}m)^2(1.39\Omega)}{4(0.11m)} = \boxed{1.0\times10^{-6}\Omega\cdot m}$

with material $\boxed{\text{nichrome}}$

21] $R_{long} = R_{short} \rightarrow \frac{\rho l_{long}}{A_1} = \frac{\rho l_{short}}{A_2}$

$\rightarrow \frac{(4)\,2 l_{short}}{\pi d^2_{long}} = \frac{4 l_{short}}{\pi d^2_{short}} \rightarrow \boxed{\frac{d_{long}}{d_{short}} = \sqrt{2}}$

27] $R = \rho \frac{l}{A} \rightarrow dR = \rho \frac{dl}{A} = \frac{dr}{4\pi\sigma r^2}$

$R = \int dR = \int_{r_1}^{r_2} \frac{dr}{4\pi\sigma r^2} = \frac{1}{4\pi\sigma}\left(\frac{-1}{r}\right)_{r_1}^{r_2}$

$= \boxed{\frac{1}{4\pi\sigma}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)}$

35] a] $I = P/V$, $\Delta P = I^2 R = \boxed{P^2 R/V^2}$ this is the power loss.

So,

$P' = (V-V')I = VI - V'I = VI - I^2R = P - I^2R$

The power loss is $\Delta P = P - P' = P - (P - I^2R)$

$= I^2R = \boxed{P^2R/V^2}$

b] since $\Delta P \propto \frac{1}{V^2}$, V should be as large as possible to minimize ΔP

43] $P = IV \rightarrow I_{bulb} = \frac{P}{V}$

$I_{total} = n I_{bulb} = n\frac{P}{V} \rightarrow n = \frac{V I_{total}}{P}$

$$= \frac{(120V)(15A)}{75W} = \boxed{24\text{ bulbs}}$$

47] $P_{electric} = P_{\text{to heat water}} \rightarrow IV = \frac{Q_{\text{heat water}}}{t} = \frac{mc\Delta T}{t}$

$$\rightarrow \frac{m}{t} = \frac{IV}{c\Delta T} = \frac{(17.5A)(240V)}{(4186 J/kg^\circ C)(6.50^\circ C)}$$

$= 0.154 kg/s \approx \boxed{0.15 kg/s}$

This is 154 mL/s

55] a] $\bar{P} = \frac{V^2_{rms}}{R} = \frac{(240V)^2}{44\Omega} = 1309 W = \boxed{1300 W}$

b] $P_{max} = 2\bar{P} = 2(1309 W) \approx \boxed{2600 W}$

$P_{min} = \boxed{0 W}$

59] $I = neAv_d \rightarrow \frac{I}{A} = (nev_d)_{He} + (nev_d)_O$

$= [(2.8\times10^{12}\text{ ions}/m^3)2(1.60\times10^{-19} C/\text{ion})(2.0\times10^6 m/s)] +$

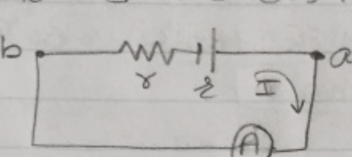
$[(7.0\times10^{11}\text{ ions}/m^3)(1.60\times10^{-19} C/\text{ion})(6.2\times10^6 m/s)]$

$= 2.486 A/m^2 \approx \boxed{2.5 A/m^2, \text{North}}$

Homework - chapter 26 [3, 17, 25, 31, 39, 51]
Jay Patel
Classical Physics - 2 (220)
OL02 - Professor U.

Q3) The terminal voltage = 0 volts

$V_{ab} = \mathcal{E} - Ir = 0 \rightarrow r = \frac{\mathcal{E}}{I} = \frac{1.5V}{25A} = \boxed{0.060\Omega}$



Q17] $P = V^2/R \rightarrow \frac{1}{R} = \frac{P}{V^2}$

$R_{eq} = \left(\frac{1}{R_{75}} + \frac{1}{R_{40}}\right)^{-1} = \left(\frac{75W}{(110V)^2} + \frac{25W}{(110V)^2}\right)^{-1}$

$= \boxed{121\Omega \simeq 120\Omega}$

Q25] a] Since there is no voltage across R_2 until the switch was closed its voltage will increase $\boxed{V_1 \& V_2 \text{ increase}; V_3 \& V_4 \text{ decrease}}$

b] By ohm's law, current is proportional to the voltage $\boxed{I_1 \& I_2 \text{ increase}; I_3 \& I_4 \text{ decrease}}$

c] Battery voltage doesn't change, the power delivered by the battery, & the voltage of the battery by the current delivered $\boxed{\text{increase}}$

d] $R_{eq} = R_1 + \left(\frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} = 125\Omega + \left(\frac{2}{125\Omega}\right)^{-1}$

$= 187.5\Omega$

$I_{total} = \dfrac{V_{battery}}{R_{eq}} = \dfrac{22.0V}{187.5\Omega} = 0.1173A = I_1$

voltage of R_1 is found by ohm's law

$V_1 = IR_1 = (0.1173A)(125\Omega) = 14.66V$

voltage of parallel

$V_P = V_{battery} - V_1 = 22.0V - 14.66V = 7.34V$

current voltage

$I_3 = \dfrac{V_P}{R_2} = \dfrac{7.34V}{125\Omega} = 0.0587A = I_4$

$\boxed{I_1 = 0.117A \quad I_3 = I_4 = 0.059A}$

So, $R_{eq} = R_1 + \left(\dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4}\right)^{-1} = 125\Omega + \left(\dfrac{3}{125\Omega}\right)^{-1} = 166.7\Omega$

$I_{total} = \dfrac{V_{bat}}{R_{eq}} = \dfrac{22.0V}{166.7\Omega} = 0.1320A = I_1$

$V_1 = IR_1 = (0.1320A)(125\Omega) = 16.5V$

$V_P = V_{battery} - V_1 = 22.0V - 16.5V = 5.5V.$

$I_2 = \dfrac{V_P}{R_2} = \dfrac{5.5V}{125\Omega} = 0.044A = I_3 = I_4$

$\boxed{I_1 = 0.132A \quad I_2 = I_3 = I_4 = 0.044A}$

$\boxed{\text{Yes,}}$ they are confirmed in part b

31] a] $V_d = V_d - V_a = -I_1(34\Omega) = -(-0.861A)(34\Omega)$

$= \boxed{29.27V \approx 29V}$

$V_d = V_d - V_a = \mathcal{E}_1 - I_2(19\Omega) = 75V - (2.41A)(19\Omega)$

$= 29.21V \approx 29V$

b] 75V battery $V_{terminal} = \mathcal{E}_1 - I_2 r$

$= 75V - (2.41A)(1.0\Omega) = \boxed{73V}$

45V battery $V_{terminal} = \mathcal{E}_2 - I_3 r$

$= 45V - (1.55A)(1.0\Omega) = \boxed{43V}$

39] $R_{153} = \left(\frac{1}{R_1} + \frac{1}{R_5}\right)^{-1} + R_3 = \left(\frac{1}{22\Omega} + \frac{1}{55\Omega}\right)^{-1} + 12\Omega$

$= 20.92\,\Omega$

for top branch

$\mathcal{E}_1 - I_{153} R_{153} = 0 \rightarrow I_{153} = \frac{\mathcal{E}}{R_{153}} = \frac{6.0V}{20.92\Omega} = 0.2868$

$V_1 = V_5 \rightarrow I_1 R_1 = I_5 R_5 \rightarrow (I_{153} - I_5) = I_5 R_5 \rightarrow$

$I_5 = I_{153}\left(\frac{R_1}{R_5 + R_1}\right) = (0.2868A)\frac{22\Omega}{37\Omega} = \boxed{0.17A}$

51] a] $V - IR_1 - IR_2 = 0 \rightarrow I = \frac{V}{R_1 + R_2} = \frac{24V}{8.8\Omega + 4.4\Omega}$

$= 1.818A$, voltage across 4.4Ω resistor.

$V_a = IR_2 = (1.818A)(4.4\Omega) = \boxed{8.0V}$

b] $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \rightarrow C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{(0.48\mu F)(0.36\mu F)}{(0.48\mu F + 0.36\mu F)}$

$= 0.2057\mu F$ $\quad Q_{eq} = VC_{eq} = (24.0V)(0.2057\mu F)$

$= 4.937\mu C = Q_1 = Q_2$

Voltage across 0.24F capacitor

$V_b = \frac{Q_2}{C_2} = \frac{4.937\mu C}{0.36\mu F} = 13.7V \approx \boxed{14V}$

c] The switch is now close. There is no current flowing in the capacitors, so resistors are again in series. 8.0V. Point must be same potential as point a, $\boxed{8.0V}$. This also means the voltage across C_2 is 8.0V, and voltage across C_1 is 16V.

d] $Q_1 = V_1 C_1 = (16V)(0.48\mu F) = 7.68\mu C$

$Q_2 = V_2 C_2 = (8.0V)(0.36\mu F) = 2.88\mu C$.

When it is open, point b has a net charge of 0.

$Q_b = -Q_1 + Q_2 = -7.68\mu C + 2.88\mu C = -4.80\mu C \approx -4.8\mu C$

Thus $\boxed{4.8\mu C}$ of charge has passed through the switch, from right to left.