No.
Date.

$$\frac{Q'}{a}+\frac{Q-Q'}{c}=\frac{Q'}{c}+\frac{Q-Q'}{b}$$

$$\frac{Q'}{a}+\frac{Q}{c}-\frac{Q'}{c}=\frac{Q'}{c}+\frac{Q}{b}-\frac{Q'}{b}$$

$$\left(\frac{1}{a}+\frac{1}{b}-\frac{2}{c}\right)Q'=\left(\frac{1}{b}-\frac{1}{c}\right)Q$$

$$Q'=\frac{\frac{1}{b}-\frac{1}{c}}{\frac{1}{a}+\frac{1}{b}-\frac{2}{c}}Q$$

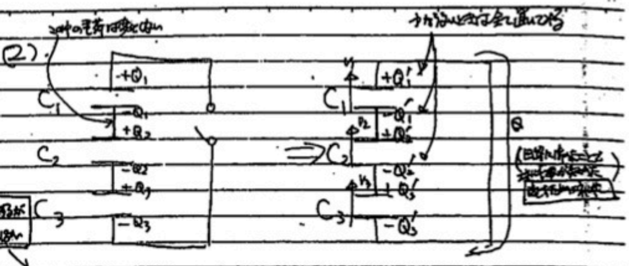
$$=\frac{\frac{c-b}{bc}}{\frac{bc+ac-2ab}{abc}}Q$$

$$=\frac{ac-ab}{bc+ac-\underset{ab+ab}{2ab}}Q$$

$$=\frac{a(c-b)}{b(c-a)+a(c-b)}Q$$

No.
Date.

(2) この中の電荷は変化しない　すなわちここは全て通じている




導体の電荷の和は変化しない

$$Q_1'-Q_2'=Q_1-Q_2\longrightarrow Q_1'=Q_1-Q_2+Q_2'$$

$$-Q_1'+Q_2'=-Q_1+Q_2\longrightarrow Q_1'=Q_1-Q_2+Q_2'$$

$$-Q_2'+Q_3'=-Q_2+Q_3\longrightarrow Q_3'=-Q_2+Q_3+Q_2'$$

$$\boxed{\underset{V_1}{\frac{Q_1'}{C_1}}+\underset{V_2}{\frac{Q_2'}{C_2}}+\underset{V_3}{\frac{Q_3'}{C_3}}=0}$$ 閉路→電位差がゼロ

$$\frac{Q_1-Q_2+Q_2'}{C_1}+\frac{Q_2'}{C_2}+\frac{-Q_2+Q_3+Q_2'}{C_3}=0$$

$$C_2C_3(Q_1-Q_2+Q_2')+C_1C_3Q_2'+C_1C_2(-Q_2+Q_3+Q_2')=0$$

$$(C_1C_2+C_2C_3+C_3C_1)Q_2'+C_2C_3Q_1-(C_1C_2+C_2C_3)Q_2$$
$$+C_1C_2Q_3=0$$

$$Q_2'=\frac{-C_2C_3Q_1+(C_1C_2+C_2C_3)Q_2-C_1C_2Q_3}{C_1C_2+C_2C_3+C_3C_1}$$

流れる電荷は

$$Q_2-Q_2'=\frac{C_3C_1Q_2+C_2C_3Q_1+C_1C_2Q_3}{C_1C_2+C_2C_3+C_3C_1}$$

~~$Q_2$の変化→$Q_1$と$Q_3$の変化→回路に流れる電荷~~

No.
Date.

(b)
$$W_1=\frac{1}{2}\left(\frac{Q_1^2}{C_1}+\frac{Q_2^2}{C_2}+\frac{Q_3^2}{C_3}\right)$$

$$W_2=\frac{1}{2}\left(\frac{Q_1'^2}{C_1}+\frac{Q_2'^2}{C_2}+\frac{Q_3'^2}{C_3}\right)$$

より残っているエネルギーは

$$W_1-W_2=\frac{1}{2}\left(\frac{Q_1^2-Q_1'^2}{C_1}+\frac{Q_2^2-Q_2'^2}{C_2}+\frac{Q_3^2-Q_3'^2}{C_3}\right)$$

[2] $(r>a)$

$$\oint_C \mathbf{B}\cdot d\mathbf{r}=\mu_0 I$$

$$2\pi r B=\mu_0 I$$

$$B=\frac{\mu_0 I}{2\pi r}\qquad (\pi a^2-\pi b^2)J=I$$

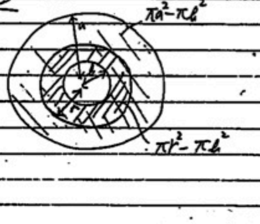
$(a>r>b)$
$$J=\frac{I}{\pi(a^2-b^2)}$$

$$2\pi r B=\mu_0(\pi r^2-\pi b^2)J$$

$$B=\frac{\mu_0 I}{2\pi r}\frac{r^2-b^2}{a^2-b^2}$$

$(b>r>0)$

$$B=0.$$



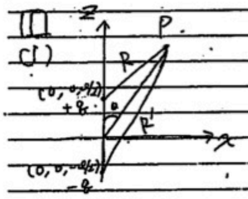

H13

No.
Date.

電気磁気学

[1]

(1)




$$\cdot\ R^2=r^2+\left(\frac{l}{2}\right)^2-2\cdot r\cdot\frac{l}{2}\cos\theta.$$ 余弦定理

$$R=\sqrt{r^2+\left(\frac{l}{2}\right)^2-rl\cos\theta}=r\sqrt{1+\left(\frac{l}{2r}\right)^2-\frac{l}{r}\cos\theta}$$

$$\cdot\ R'^2=r^2+\left(\frac{l}{2}\right)^2-2\cdot r\cdot\frac{l}{2}\cos(\pi-\theta)$$

$$R'=\sqrt{r^2+\left(\frac{l}{2}\right)^2+rl\cos\theta}=r\sqrt{1+\left(\frac{l}{2r}\right)^2+\frac{l}{r}\cos\theta}$$

$$R\fallingdotseq r\sqrt{1-\frac{l}{r}\cos\theta}\qquad R'\fallingdotseq r\sqrt{1+\frac{l}{r}\cos\theta}$$

$$=r\left(1-\frac{l}{r}\cos\theta\right)^{\frac{1}{2}}\qquad =r\left(1+\frac{l}{2r}\cos\theta\right)$$

$$\fallingdotseq r\left(1-\frac{l}{2r}\cos\theta\right)\qquad \boxed{(1+x)^a\fallingdotseq 1+ax}$$

$$V=\frac{q}{4\pi\varepsilon_0}\left(\frac{1}{R}-\frac{1}{R'}\right)=\frac{q}{4\pi\varepsilon_0 r}\left(\frac{1}{1-\frac{l}{2r}\cos\theta}-\frac{1}{1+\frac{l}{2r}\cos\theta}\right).$$

$$\left(1-\frac{l}{2r}\cos\theta\right)^{-1}\approx 1+\frac{l}{2r}\cos\theta$$

$$\fallingdotseq\frac{q}{4\pi\varepsilon_0 r}\left(1+\frac{l}{2r}\cos\theta-1+\frac{l}{2r}\cos\theta\right)$$

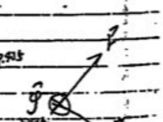
$$=\frac{q}{4\pi\varepsilon_0 r}\left(\frac{l}{r}\cos\theta\right)=\frac{ql\cos\theta}{4\pi\varepsilon_0 r^2}=\frac{p\cos\theta}{4\pi\varepsilon_0 r^2}.$$

Eを極座標で出す

(2) $\mathbf{E}=-\nabla V\ \left(\mathbf{E}=-\mathrm{grad}\,V\right)$

$$=-\left(\hat{r}\frac{\partial V}{\partial r}+\hat{\theta}\frac{1}{r}\frac{\partial V}{\partial\theta}+\hat{\varphi}\frac{1}{r\sin\theta}\frac{\partial V}{\partial\varphi}\right)$$

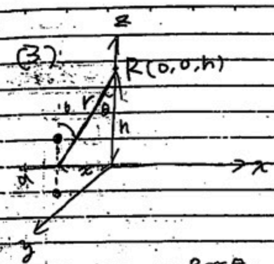
$$=-\left\{\hat{r}\left(-\frac{p\cos\theta}{2\pi\varepsilon_0 r^3}\right)+\hat{\theta}\frac{1}{r}\left(-\frac{p\sin\theta}{4\pi\varepsilon_0 r^2}\right)\right\}$$



$$=\underbrace{\hat{r}\frac{p\cos\theta}{2\pi\varepsilon_0 r^3}}_{\hat{r}\text{成分}}+\underbrace{\hat{\theta}\frac{p\sin\theta}{4\pi\varepsilon_0 r^3}}_{\hat{\theta}\text{成分}}.$$

No.
Date.

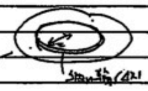
(3)




$r=\sqrt{x^2+h^2}$

$\cos\theta = \dfrac{h}{r} = \dfrac{h}{\sqrt{x^2+h^2}}$

(1)より $V = \dfrac{p\cos\theta}{4\pi\varepsilon_0 r^2} = \dfrac{ph}{4\pi\varepsilon_0 (x^2+h^2)^{3/2}}$



全部でNコなので 0〜aの範囲で1周につき $\frac{N}{a}$ コあると考えると

半径xからの電位は まず1周分の和

$V_x = \dfrac{Ph}{4\pi\varepsilon_0 (x^2+h^2)^{3/2}} \times \underbrace{\dfrac{N}{a}}_{[illegible]} = \dfrac{NPh}{4\pi\varepsilon_0 a (x^2+h^2)^{3/2}}$

$V = \int_0^a \dfrac{NPh}{4\pi\varepsilon_0 a (x^2+h^2)^{3/2}} dx.$

$x = h\tan\theta$ とおくと. $x^2+h^2 = h^2(1+\tan^2\theta) = \dfrac{h^2}{\cos^2\theta}$

$dx = \dfrac{h}{\cos^2\theta} d\theta$ $\quad (x^2+h^2)^{3/2} = \dfrac{h^3}{\cos^3\theta}$

| $x$ | $0 \to a$ |
|---|---|
| $\theta$ | $0 \to \theta_0$ $\tan\theta_0 = \frac{a}{h}$ |

$V = \dfrac{NPh}{4\pi\varepsilon_0 a}\int_0^{\theta_0} \dfrac{\cos\theta}{h} d\theta = \dfrac{NP}{4\pi\varepsilon_0 a}\Big[\sin\theta\Big]_0^{\theta_0}$

$\sin\theta_0 = \dfrac{a}{r} = \dfrac{a}{\sqrt{a^2+h^2}}$ $\quad = \dfrac{NPa}{2\pi\varepsilon_0 a}$

$\dfrac{NP}{4\pi\varepsilon_0 a}\cdot\dfrac{a}{r} = \dfrac{NP}{4\pi\varepsilon_0 r}$

No.
Date.

$\boxed{2}$

(1) $C = \varepsilon_0 \dfrac{S}{d} = \varepsilon_0 \dfrac{\pi a^2}{d}$

$V = RI + \boxed{\frac{1}{C}\int I\,dt}$ コンデンサの式! $\quad I = \frac{dq}{dt}$ より

~~$V = R\frac{dq}{dt} + \frac{q}{C}$~~ → ラプラス変換の方がラク

$\dfrac{V}{s} = RI + \dfrac{1}{C}\left(\dfrac{I}{s} + \dfrac{q_0}{s}\right) = RI + \dfrac{I}{Cs}$

~~$q = CV + C' e^{-\frac{1}{RC}t}$~~

~~$t=0$ で $q=0$ より~~

~~$0 = CV + C' \to C' = -CV.$~~

~~$\therefore q = CV(1-e^{-\frac{1}{RC}t})$~~

$I = \dfrac{V}{R} e^{-\frac{1}{RC}t}$

$= \dfrac{V}{R} e^{-\frac{d}{R\varepsilon_0\pi a^2}t}$ [C/s] 群[30]

(2) $J_d = \dfrac{I}{\pi a^2} = \dfrac{V}{\pi a^2 R} e^{-\frac{d}{R\varepsilon_0 \pi a^2}t}$ [C/s·m²]

(3) $\oint H\cdot dl = I$

($r<a$) 囲まれたI

$2\pi r H = J_d \cdot \pi r^2.$

$H = \dfrac{1}{2\pi r}\dfrac{Vr^2}{a^2 R} e^{-\frac{d}{R\varepsilon_0\pi a^2}t}$

$= \dfrac{rV}{2\pi a^2 R} e^{-\frac{d}{R\varepsilon_0\pi a^2}t}.$

($r>a$)

$2\pi r H = I$ $\quad$ 方向 $\hat{\varphi}$

$H = \dfrac{V}{2\pi r R} e^{-\frac{d}{R\varepsilon_0\pi a^2}t}$

No.
Date.

(4) $\underset{\text{[illegible]}}{P(t)} = I^2R = \dfrac{V^2}{R} e^{-\frac{2d}{R\varepsilon_0\pi a^2}t}$

$t\to\infty \Rightarrow \dfrac{V^2}{R}$

$P_{all} = \int_0^\infty P(t)\,dt$

全部

$= \dfrac{V^2}{R}\left(-\dfrac{R\varepsilon_0\pi a^2}{2d}\right)(-1)$

$= \dfrac{\varepsilon_0\pi a^2 V^2}{2d}$ 同じ

コンデンサに蓄えられるエネルギーは.

静電エネルギー $W = \dfrac{1}{2}QV = \dfrac{1}{2}CV^2 = \dfrac{\varepsilon_0\pi a^2 V^2}{2d}$

$\boxed{W = \int_0^\infty P(t)\,dt}$ [エネルギー. 仕事 > 電力 ($E$, $W$, $P$)]

H12

No.
Date. 7

電気磁気学

1a. $W = qV$ 電位

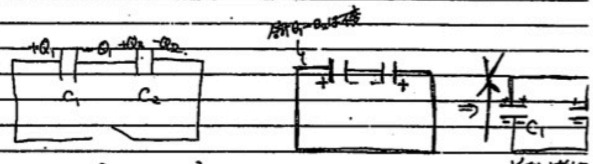
1) $dW = dq(\phi_1 - \phi_2)$

各のせいnan?

2) $C = \dfrac{Q}{V} = \dfrac{q}{\phi_1 - \phi_2}$ $\quad Q = CV$, V

3) $W = \dfrac{QV}{2} = \dfrac{Q^2}{2C}$ $\quad \boxed{W = \frac{1}{2}CV^2 = \frac{Q}{2}}$

1b.




逆向に考える

$W = \frac{1}{2}(C_1+C_2)V$

4) $W_1 = \dfrac{Q_1^2}{2C_1} + \dfrac{Q_2^2}{2C_2} = \dfrac{1}{2}\left(\dfrac{Q_1^2}{C_1} + \dfrac{Q_2^2}{C_2}\right)$

5) $C = C_1 + C_2$ 合計電荷($Q_1 - Q_2$)

$V = \dfrac{Q_1 - Q_2}{C} = \dfrac{Q_1 - Q_2}{C_1 + C_2}$

$W_2 = \dfrac{1}{2}CV^2 = \dfrac{1}{2}\dfrac{(Q_1-Q_2)^2}{C_1+C_2}$ $\quad \dfrac{Q_1^2C_2 + Q_2^2C_1}{C_1C_2}$

6) $W_2 - W_1 = \dfrac{1}{2}\left\{\dfrac{(Q_1-Q_2)^2}{C_1+C_2} - \left(\dfrac{Q_1^2}{C_1} + \dfrac{Q_2^2}{C_2}\right)\right\}$

$= \dfrac{1}{2}\dfrac{C_1C_2(Q_1^2 - 2Q_1Q_2 + Q_2^2) - C_2(C_1+C_2)Q_1^2 - C_1(C_1+C_2)Q_2^2}{(C_1+C_2)C_1C_2}$

$= \dfrac{1}{2}\dfrac{-2C_1C_2Q_1Q_2 - C_2^2Q_1^2 - C_1^2Q_2^2}{(C_1+C_2)C_1C_2}$

$= -\dfrac{1}{2}\dfrac{(C_1Q_2 + C_2Q_1)^2}{(C_1+C_2)C_1C_2}$ $\quad$ 回路に電流が流れた 熱になった。ジュール熱