PC212 Tutorial Problem
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Definition

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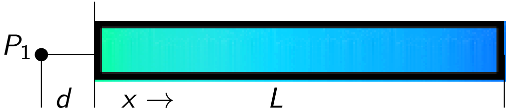

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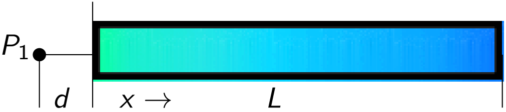

$V(P_1) = ?$

- $L = 12.0cm$

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We want to find $V(P_1)$

Before Math

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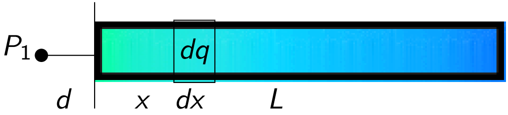
$$V = \frac{1}{4\pi\epsilon_0}\int \frac{dq}{r}$$

$$V = -\int_i^f \vec{E}\cdot\vec{ds}$$



$$dq = \lambda dx$$

$$dq = cxdx$$

Calculations

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$$dV = \frac{1}{4\pi\epsilon_0}\frac{dq}{r}$$

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$$
\begin{aligned}
dV &= \frac{1}{4\pi\epsilon_0}\frac{dq}{r} \\
&= \frac{1}{4\pi\epsilon_0}\frac{cxdx}{x+d}
\end{aligned}
$$

Calculations

$$dV = \frac{1}{4\pi\epsilon_0}\frac{dq}{r}$$
$$= \frac{1}{4\pi\epsilon_0}\frac{cxdx}{x+d}$$
$$V = \int dV$$

Calculations

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\begin{aligned}
dV &= \frac{1}{4\pi\epsilon_0}\frac{dq}{r} \\
&= \frac{1}{4\pi\epsilon_0}\frac{cxdx}{x+d} \\
V &= \int dV \\
&= \int_0^L \frac{1}{4\pi\epsilon_0}\frac{cx}{x+d}dx
\end{aligned}
$$

Calculations

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dV &= \frac{1}{4\pi\epsilon_0}\frac{dq}{r} \\
&= \frac{1}{4\pi\epsilon_0}\frac{cxdx}{x+d} \\
V &= \int dV \\
&= \int_0^L \frac{1}{4\pi\epsilon_0}\frac{cx}{x+d}dx \\
&= \frac{c}{4\pi\epsilon_0}\int_0^L \frac{x}{x+d}dx
\end{aligned}
$$

$$V = \frac{c}{4\pi\epsilon_0}\int_0^L \frac{x}{x+d}dx$$

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$$= \frac{c}{4\pi\epsilon_0}\int_0^L \frac{x+d}{x+d} - \frac{d}{x+d}\,dx$$

$$V = \frac{c}{4\pi\epsilon_0}\int_0^L \frac{x}{x+d}dx$$
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$$= \frac{c}{4\pi\epsilon_0}\int_0^L 1 - \frac{d}{x+d}dx$$

$$
\begin{aligned}
V &= \frac{c}{4\pi\epsilon_0}\int_0^L \frac{x}{x+d}dx \\
&= \frac{c}{4\pi\epsilon_0}\int_0^L \frac{x+d}{x+d} - \frac{d}{x+d}dx \\
&= \frac{c}{4\pi\epsilon_0}\int_0^L 1 - \frac{d}{x+d}dx \\
&= \frac{c}{4\pi\epsilon_0}\left[\int_0^L 1dx - \int_0^L \frac{d}{x+d}dx\right]
\end{aligned}
$$

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V &= \frac{c}{4\pi\epsilon_0}\int_0^L \frac{x}{x+d}dx \\
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&= \frac{c}{4\pi\epsilon_0}\int_0^L 1 - \frac{d}{x+d}dx \\
&= \frac{c}{4\pi\epsilon_0}\left[\int_0^L 1dx - \int_0^L \frac{d}{x+d}dx\right] \\
&= \frac{c}{4\pi\epsilon_0}\left[x - d\ln\left(x+d\right)\right]_0^L
\end{aligned}
$$

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&= \frac{c}{4\pi\epsilon_0}\int_0^L 1 - \frac{d}{x+d}dx \\
&= \frac{c}{4\pi\epsilon_0}\left[\int_0^L 1dx - \int_0^L \frac{d}{x+d}dx\right] \\
&= \frac{c}{4\pi\epsilon_0}\left[x - d\ln\left(x+d\right)\right]_0^L \\
&= \frac{c}{4\pi\epsilon_0}\left[\left(L - d\ln\left(L+d\right)\right) - \left(0 - d\ln\left(0+d\right)\right)\right]
\end{aligned}
$$

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V &= \frac{c}{4\pi\epsilon_0}\int_0^L \frac{x}{x+d}dx \\
&= \frac{c}{4\pi\epsilon_0}\int_0^L \frac{x+d}{x+d} - \frac{d}{x+d}dx \\
&= \frac{c}{4\pi\epsilon_0}\int_0^L 1 - \frac{d}{x+d}dx \\
&= \frac{c}{4\pi\epsilon_0}\left[\int_0^L 1dx - \int_0^L \frac{d}{x+d}dx\right] \\
&= \frac{c}{4\pi\epsilon_0}\left[x - d\ln\left(x+d\right)\right]_0^L \\
&= \frac{c}{4\pi\epsilon_0}\left[\left(L - d\ln\left(L+d\right)\right) - \left(0 - d\ln\left(0+d\right)\right)\right] \\
&= \frac{c}{4\pi\epsilon_0}\left[L - d\ln\left(L+d\right) + d\ln d\right]
\end{aligned}
$$

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&= \frac{c}{4\pi\epsilon_0}\int_0^L 1 - \frac{d}{x+d}dx \\
&= \frac{c}{4\pi\epsilon_0}\left[\int_0^L 1dx - \int_0^L \frac{d}{x+d}dx\right] \\
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&= \frac{c}{4\pi\epsilon_0}\left[\left(L - d\ln\left(L+d\right)\right) - \left(0 - d\ln\left(0+d\right)\right)\right] \\
&= \frac{c}{4\pi\epsilon_0}\left[L - d\ln\left(L+d\right) + d\ln d\right] \\
&= \frac{c}{4\pi\epsilon_0}\left[L - d\ln\left(\frac{L+d}{d}\right)\right]
\end{aligned}
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&= \frac{c}{4\pi\epsilon_0}\left[\int_0^L 1dx - \int_0^L \frac{d}{x+d}dx\right] \\
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&= \frac{c}{4\pi\epsilon_0}\left[\left(L - d\ln\left(L+d\right)\right) - \left(0 - d\ln\left(0+d\right)\right)\right] \\
&= \frac{c}{4\pi\epsilon_0}\left[L - d\ln\left(L+d\right) + d\ln d\right] \\
&= \frac{c}{4\pi\epsilon_0}\left[L - d\ln\left(\frac{L+d}{d}\right)\right] \\
&= \frac{c}{4\pi\epsilon_0}\left[L - d\ln\left(1+\frac{L}{d}\right)\right]
\end{aligned}
$$

$$V = \frac{c}{4\pi\epsilon_0}\left[L - d\ln\left(1+\frac{L}{d}\right)\right]$$

$$
\begin{aligned}
V &= \frac{c}{4\pi\epsilon_0}\left[L - d\ln\left(1+\frac{L}{d}\right)\right] \\
&= \frac{28.9pC/m^2}{4\pi\epsilon_0}\left[12.0cm - 3.00cm\ln\left(1+\frac{12.0cm}{3.00cm}\right)\right]
\end{aligned}
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V &= \frac{c}{4\pi\epsilon_0}\left[L - d\ln\left(1+\frac{L}{d}\right)\right] \\
&= \frac{28.9pC/m^2}{4\pi\epsilon_0}\left[12.0cm - 3.00cm\ln\left(1+\frac{12.0cm}{3.00cm}\right)\right] \\
&\approx \frac{28.9x10^{-12}}{4\pi 8.85x10^{-12}}\left[12x10^{-2} - 3x10^{-2}\ln\left(1+4\right)\right]
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&\approx \frac{28.9x10^{-12}}{4\pi 8.85x10^{-12}}\left[12x10^{-2} - 3x10^{-2}\ln\left(1+4\right)\right] \\
&\approx 0.2598x10^{-2}\left[12 - 3(1.609)\right]
\end{aligned}
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&\approx \frac{28.9x10^{-12}}{4\pi 8.85x10^{-12}}\left[12x10^{-2} - 3x10^{-2}\ln(1+4)\right] \\
&\approx 0.2598x10^{-2}\left[12 - 3(1.609)\right] \\
&\approx 0.2598x10^{-2}\left[7.17\right] = 1.86x10^{-2}V = 18.6mV
\end{aligned}
$$