Physics 172
Spring Quarter 1981
May 1, 1981

2nd Midterm

Key

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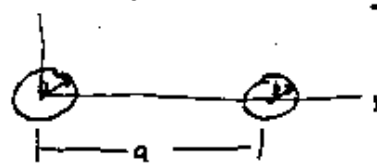
# scores = 150
mean = 6.72
s.d. = 1.94

PROBLEM 5A

Calculate the capacitance per meter of two long parallel wires a distance a apart. (Note: The electric field cannot be calculated from Gauss' Law.)



assume $a \gg b$

Use Gauss' Law to find the field due to one wire

$$\oint \vec{E}\cdot d\vec{a} = \frac{q}{\epsilon_0}$$

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

$$E_r = \frac{q}{2\pi r \ell \epsilon_0}\hat{r}$$

define $\lambda = \frac{q}{\ell}$

$$E_r = \frac{\lambda}{2\pi\epsilon_0}\cdot\frac{1}{r}$$

Superpose fields due to two wires on the x-axis.

$$E_x = \frac{\lambda}{2\pi\epsilon_0}\left(\frac{1}{x} + \frac{1}{a-x}\right)$$

$$V = -\int \vec{E}_x \cdot d\vec{x}$$

$$V = -\int_b^{a-b} \frac{\lambda}{2\pi\epsilon_0}\left(\frac{1}{x} + \frac{1}{a-x}\right)dx$$

$$= -\frac{\lambda}{2\pi\epsilon_0}\left[\ln x - \ln(a-x)\right]_b^{a-b}$$

$$= \frac{\lambda}{2\pi\epsilon_0}\left(2\ln\left(\frac{a}{a-b}\right) + \ln\left(\frac{b}{a-b}\right)\right)$$

$$C = \frac{q}{V} \qquad C/\ell = \frac{Q}{\ell V} = \frac{\lambda}{V}$$

$$C = \frac{2\pi\epsilon_0}{2\ln\left(\frac{b}{a-b}\right)} = \frac{\pi\epsilon_0}{\ln\left(\frac{b}{a-b}\right)}$$

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