Physics 302
Winter Quarter 1991
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George Williams

$\boxed{4}$

THIRD TERM

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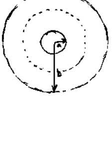
Discussion Instructor (circle one): Davis DeTienne Hamed Molina Paul Zhang

Discussion Section #______

SHOW ALL WORK!!!!!
REPORT ALL NUMBERS TO THREE SIGNIFICANT FIGURES!
Use the conversion constants and data given on the front page.

A wire has a radius is 0.25 mm and a length of 20 cm. The wire is in the center of a metal tube whose inner radius is 1.55 cm. A potential of 4000 V is applied between the wire and the tube. Calculate the energy stored in the electric field between the wire and tube.



Gausses Law Gives

$$\int \vec{E}\cdot d\vec{A} = E\cdot 2\pi r l = \frac{\lambda l}{\epsilon_0}$$

l = length of Gaussian surface

$$E = \frac{\lambda}{2\pi r\epsilon_0}$$

Integrating this from one conductor to the next.

$$V = \int_a^b \vec{E}\cdot d\vec{r} = \frac{\lambda}{2\pi\epsilon_0}\ln\left(\frac{b}{a}\right)$$

from here $\lambda = \dfrac{2\pi\epsilon_0 V}{\ln\left(\frac{b}{a}\right)}$

Now we can calculate the capacitance and then the energy stored.

$$C = \frac{q}{V} = \frac{\lambda L}{\frac{\lambda}{2\pi\epsilon_0}\ln\left(\frac{b}{a}\right)} = \frac{2\pi\epsilon_0 L}{\ln\left(\frac{b}{a}\right)}$$

$$U = \frac{1}{2}CV^2 = \frac{\pi\epsilon_0 L}{\ln\left(\frac{b}{a}\right)}V^2 = \boxed{2.16\times10^{-5}\text{ J}}$$

Alternately we can integrate the energy density over the volume between the two conductors. (u = energy density, U = total energy)

$$u = \frac{1}{2}\epsilon_0 E^2$$

$$U = \int u\,dv = \int_a^b \frac{1}{2}\epsilon_0\left(\frac{\lambda}{2\pi r\epsilon_0}\right)^2 2\pi r L\,dr = \frac{\lambda^2 L}{4\pi\epsilon_0}\int_a^b \frac{dr}{r} = \frac{L}{4\pi\epsilon_0}\left(\frac{2\pi\epsilon_0 V}{\ln\left(\frac{b}{a}\right)}\right)^2 \ln\left(\frac{b}{a}\right)$$

$$= \frac{\pi\epsilon_0 L V^2}{\ln\left(\frac{b}{a}\right)}$$