Print name________________________

ID number________________________

Section in which you are registered (sec 1 = 9 AM lec, sec 2 = 10 AM lec)________

Physics 241E, section 2, Test No. 1

October 1, 2003, 10:00-10:50 AM

On the bubble sheet, fill in your student id number, and in addition write your name and your section in the appropriate spot. After you have found an answer, fill in the appropriate bubbles on your bubble sheet—note any special instructions on this point in the problem itself. No notes or books are allowed during the exam, nor is any consultation with anyone but me. You can only take this exam in one of the two sessions. YOU MUST TURN IN THIS COVER SHEET WITH YOUR BUBBLE SHEET—WITHOUT IT, I CAN'T GUARANTEE YOU PROPER CREDIT.

Write out an authorized form of the pledge here, and sign it.

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Signed____________________

formulas you might need: $\frac{d}{dx}x^n = nx^{n-1}$; $\int x^n dx = \frac{x^{n+1}}{n+1}$.

$1/(4\pi\varepsilon_0) \cong 9 \times 10^9$ SI units; magnitude of electron charge = 1.6×10^{-19} C.

$R = \rho L/A$; $C = \varepsilon_0 A/d$.

1. A 10 μF capacitor is charged to 100 V. At time $t_0 = 0$ a resistor $R = 10^4\ \Omega$ is put across its terminals. At what time t will the voltage across the capacitor be 50 V?

(a) 39 ms

(b) 59 ms

(c) 69 ms

(d) 1.3 s

(e) 2.6 s

With these init conditions,

$V = V_0 \exp\left(-\frac{t}{RC}\right)$

$V = \frac{1}{2} V_0$ when $\exp\left(-\frac{t}{RC}\right) = \frac{1}{2}$

$\Rightarrow \frac{t}{RC} = \ln 2 = 0.69 \Rightarrow t = RC(0.69) = (10)(10^{-6})(10^4)(0.69)$ s $= 69$ ms

The next problem and problems #3 and # 4 all refer to an infinitely-long solid cylinder—non-conducting—of radius R, carrying a uniform volume charge density ρ.

2. What is the electric field, direction and magnitude, at a radial distance r ($r < R$) from the axis of the cylinder?

(a) E = a constant, radially outward for positive charge, inward for negative charge.

(b) $E = \rho/(2\pi\varepsilon_0 r)$, radially outward for positive charge, inward for negative charge.

(c) 0

(d) $E = \rho r/(2\varepsilon_0)$, radially outward for positive charge, inward for negative charge.

(e) $E = \rho r/2$, forming circles inside the wire.

Symm. ⇒ field is radial, outward for ρ positive.

Erect a Gaussian surface in the form of a cylinder, length L & of radius $r < R$ centered on the axis. Flux through ends $= 0$, through sides $= (E)(\text{area of sides}) = E(2\pi r L)$.

Uniform charge density ⇒ charge in our Gaussian cylinder is $\rho \times$ vol enclosed by Gaussian surface $= \rho \pi r^2 L$

Gauss' law $E(2\pi r L) = \frac{\rho \pi r^2 L}{\varepsilon_0}$ or $E = \frac{\rho r}{2\varepsilon_0}$

3. What is the electric potential, relative to a point a distance a (*outside* the cylinder) from the axis, at a distance r ($r > R$) from the axis? That is, find $V(r) - V(a)$.

(a) $-\frac{\rho R}{2\pi\varepsilon_0}\left(\frac{1}{r^2}-\frac{1}{a^2}\right)$

(b) $-\frac{\rho}{2\varepsilon_0}\left(\frac{1}{r}-\frac{1}{a}\right)$

(c) $\frac{\rho R^2}{2\varepsilon_0}\ln\left(\frac{r}{a}\right)$

(d) $\frac{\rho}{2\varepsilon_0}\left(\frac{1}{r}-\frac{1}{a}\right)$

(e) $-\frac{\rho R^2}{2\varepsilon_0}\ln\left(\frac{r}{a}\right)$

To get potential, first find field. All points are outside. Same symm, method as in Prob. 2, except charge enclosed is the (vol. of wire) × ρ

Then E radially outward (pos. ρ), magnitude.

$$E = \frac{\rho R^2}{2\varepsilon_0 r}.$$

Pot. diff only dep. on radius.

$$V(r) - V(a) = -\int_a^r dr'\, E(r') = -\int_a^r dr'\, \frac{\rho R^2}{2\varepsilon_0 r'}$$

$$= -\frac{\rho R^2}{2\varepsilon_0}(\ln r - \ln a) = -\frac{\rho R^2}{2\varepsilon_0} \ln \frac{r}{a}$$

4. What is the energy density at a point a distance r ($r > R$) from the axis?

(a) cannot be determined without calculating the work needed to charge the system.

(b) $\varepsilon_0 \frac{\rho^2 r^2}{2}$

(c) $\frac{\rho^2 R^3}{8\pi\varepsilon_0 r}$

(d) $\frac{\rho^2 r^4}{2\varepsilon_0 R^2}$

(e) $\frac{\rho^2 R^4}{8\varepsilon_0 r^2}$

In prob. 3 found E, and charge density is

$$u = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0 \frac{\rho^2 R^4}{4\varepsilon_0^2 r^2} = \frac{1}{8\varepsilon_0}\frac{\rho^2 R^4}{r^2}$$

5. An electric iron is marked 110 V, 1500 W. (Assume that the voltage is not time dependent, and in fact it is when it comes out of the wall.) What is the approximate resistance of the heating element?

(a) 8 Ω

(b) 15 Ω

(c) 25 Ω

(d) 110 Ω

(e) none of the above

$$\underset{1500\,W}{P} = I^2 R = \frac{\overset{110}{V^2}}{R} \Rightarrow$$

$$R = \frac{V^2}{P} = \frac{(110)^2}{1500}\ \Omega = 8\ \Omega$$