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POINTS:

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Midterm 1 physics 230, 23-28 April 15, 2010

NOTE: TO ENSURE FULL CREDIT EMPHASIZE YOUR ANSWERS AND **INCLUDE DIMENSIONS**. SPECIFY WHICH PRINCIPLES OR LAWS YOU ARE USING. EXPLAIN BRIEFLY WHAT YOU ARE TRYING TO DO. ORGANIZE YOUR WORK LOGICALLY. USE DRAWINGS! Use the correct number of significant figures. **USE scientific notation for numbers larger than 1000 and smaller than 1/1000. Unless otherwise specified, do not use more than 3 significant figures.**

$k_e = \frac{1}{4\pi\varepsilon_0} = 8.89\cdot 10^9$; $\varepsilon_0 = 8.85\cdot 10^{-12}\, S.I.$;parallel plate capacitor: $E = \frac{\sigma}{\varepsilon_0}; C = \kappa\frac{\varepsilon_0 A}{d}$

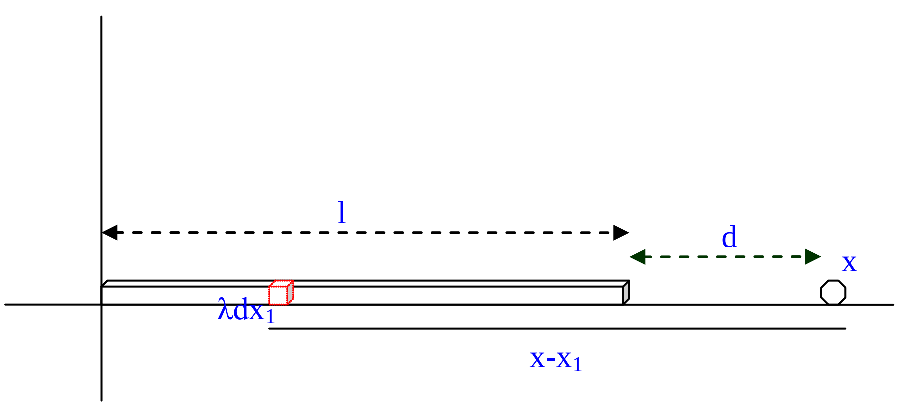
$E = \frac{Q}{4\pi\varepsilon_0}\frac{1}{r^2}; \vec{E} = -\overrightarrow{grad}\cdot V; \Delta V_{ab} = -\int_a^b \vec{E}\cdot d\vec{s}; C = \frac{Q}{\Delta V}; \vec{F} = q\vec{E}; U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}C(\Delta V)^2;$

$dW = qdV; U_{dipole} = -\vec{p}\bullet\vec{E}; \vec{\tau} = \vec{p}\times\vec{E}; q = C\varepsilon\left(1 - e^{\frac{-t}{RC}}\right); q = 1.60\cdot 10^{-19} C; m_{proton} = 1.66\cdot 10^{-27} kg$

$coaxial: C = L/2k_e \ln\frac{b}{a}; I = \dot{Q} = \iint_{surface} \vec{j}\,d\vec{A}; \vec{j} = nq\vec{v}_d; \vec{j} = \sigma\vec{E}; \rho_\Omega = \frac{1}{\sigma}; \frac{\Delta\rho}{\rho} = \alpha\Delta T$

$copper: \rho_\Omega = 1.7\cdot 10^{-8}\,\Omega m\ at\ 20°C; \alpha = 3.9\cdot 10^{-5}/C°; \Delta V = RI; P = I\Delta V = RI^2; \Delta V = \varepsilon - rI$

1. [10] Calculate the field created by a uniformly charged rod of length l with charge density λ. The point where you want to calculate the field is located at a distance d from the end of the rod along the axis of the rod. The charge is distributed over the rod of length l.



Solution: $\vec{E} = k_e \dfrac{\lambda L}{d(d+L)} \vec{i}$

2. [10] A proton with an initial velocity v_{0x} =5.00E5 m/s enters a uniform vertical electric field with of 2.45E2 V/m of a parallel plate capacitor at the center plane. The capacitor has a thickness of 3.55cm. Where and when will the proton hit the capacitor plate? What is its vertical and horizontal velocity at that point?

$t = 1.23 \cdot 10^{-6} s; x = 0.613m$

$v_{0x} = v_x = 5.00E5 \dfrac{m}{s}; v_y = 2.90E4 \dfrac{m}{s}$

3. [10] Calculate the capacitance of a coaxial cable with inner radius a and outer radius b. Start with Gauss's law to calculate the electric field inside of the capacitor. Then calculate the potential difference between the two cylinders, which you may consider to be infinitely thin.

$E = \dfrac{2k_e\lambda}{r}; \Delta V = 2k_e \ln\dfrac{b}{a};$

$C = \dfrac{L}{2k_e \ln\dfrac{b}{a}}$

4. [10]

$$n_V = 6.02E28 / m^3, v_d = 0.149 \frac{mm}{s}$$

5. [10] Calculate the required resistance of an immersion heater that increases the temperature of 1.80 liters of water from 20.0ºC to 75.0ºC in 12.0 minutes while operating at 120 Volts.

Solution: R=25Ω

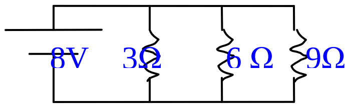
6. [10] Show through integration that the differential form of $\alpha = \frac{1}{\rho}\frac{d\rho}{dT}$ leads to $\rho = \rho_0\left[1+\alpha\left(T-T_0\right)\right]$. Solve for ρ through separation of the variables and integrating. Then use the linear approximation of $e^x=1+x$.

$$\rho_\Omega\left(T\right)=\rho_0 e^{\alpha\left(T-T_0\right)} \approx \rho_0\left[1+\alpha\left(T-T_0\right)\right]$$

7. [10] A battery has an emf of 15.0 V. The terminal voltage of the battery is 11.6 V when it is delivering 20.0 W of power to an external resistor R. Find the value of R and the value for the internal resistance of the battery.

$$R = 6.73\Omega; r = 1.97\Omega$$

8. [10] Calculate the current in the 6 Ohm resistor. Calculate the equivalent resistance of the circuit. How much power is delivered to the 9 Ohm resistor.



$I_6 = 1.33A; R_{eq} = 1.64\Omega; P_9 = 7.11W$

9. [10] Calculate the equivalent capacitance of two capacitors in series. One with 5.00μF, the other with 15.0 μF connected to a 9.00 V battery. Find the potential difference across each capacitor and its charge. Make a drawing.

$C_{eq} = 3.75\mu F \Rightarrow Q = 33.8\mu C$

$\Delta V_5 = 6.76V; \Delta V_{15} = 2.25V$

10. [10] A 4.00MΩ resistor and a 3.00μF capacitor are connected in series with a 12.0V power supply. Find the time constant for the circuit. How long does it take for the capacitor to be charged to half is maximum capacity. Derive the result by making a drawing of a charging RC circuit and solving the differential equation.

$\tau = 12s; 8.3s$