Physics 5C - Second Midterm

Wednesday, May 22, 2-2:50PM

UCLA / Spring 2024 / Brian Naranjo

NAME ____________________

SIGNATURE ____________________

ID ____________________

- Wait until instructed to begin.
- This exam is closed-book, with no external notes or scratch paper, and no electronic devices.
- Use this coversheet for scratch work. *If* needed, extra scratch paper is available.
- If your work continues on the scratch page, then make a note in your solution.
- You may unstaple your exam, but please keep the pages in order and include this coversheet.
- Present your photo ID when you hand in your exam.

Electric field

$$k = \frac{1}{4\pi\epsilon_0} \qquad |\mathbf{F}| = \frac{1}{4\pi\epsilon_0}\frac{|q_1 q_2|}{r^2}$$

$$\mathbf{E}(x,y,z) = \frac{\mathbf{F}_q(x,y,z)}{q}$$

$$|\mathbf{E}| = \frac{1}{4\pi\epsilon_0}\frac{|q|}{r^2} \qquad |\mathbf{E}| = \frac{1}{4\pi\epsilon_0}\frac{|Q_{\text{in}}(r)|}{r^2}$$

$$\sigma = Q/A \qquad |\mathbf{E}| = \frac{|\sigma|}{2\epsilon_0}$$

$$p = qd \qquad \tau = pE\sin\phi$$

$$\mathbf{E}_{\text{axis}} \approx \frac{1}{4\pi\epsilon_0}\frac{2\mathbf{p}}{r^3} \qquad \mathbf{E}_{\text{plane}} \approx -\frac{1}{4\pi\epsilon_0}\frac{\mathbf{p}}{r^3}$$

Electric potential

$$U = qV \qquad E_s \approx -\Delta V/\Delta s$$

$$V = \sum_i \frac{1}{4\pi\epsilon_0}\frac{q_i}{r_i} \qquad U = \frac{1}{4\pi\epsilon_0}\sum_{\text{all pairs}}\frac{q_i q_j}{r_{ij}}$$

$$V = -E_0 x \qquad U = -qE_0 x$$

$$U = -pE\cos\phi \qquad V = \frac{p\cos\theta}{4\pi\epsilon_0 r^2}$$

$$U_0 + K_0 = U_1 + K_1 \qquad 0 = \sum_{\text{loop}}(\Delta V)_i$$

Capacitance

$$Q = VC \qquad C_{\text{plate}} = \frac{\kappa\epsilon_0 A}{d}$$

$$U = \frac{Q^2}{2C} = \frac{QV}{2} = \frac{CV^2}{2} \qquad u_E = \frac{1}{2}\kappa\epsilon_0 E^2$$

$$C_p = C_1 + C_2 + \cdots \qquad 1/C_s = 1/C_1 + 1/C_2 + \cdots$$

$$E = E_0/\kappa \qquad C = \kappa C_0$$

Current and resistance

$$R = \frac{\rho L}{A} \qquad V = IR$$

$$I_{\text{rms}} = I_0/\sqrt{2} \qquad V_{\text{rms}} = V_0/\sqrt{2}$$

$$P = VI = V^2/R = I^2 R$$

$$P_{\text{avg}} = V_{\text{rms}} I_{\text{rms}} = V_{\text{rms}}^2/R = I_{\text{rms}}^2 R$$

Circuits

$$\sum I_{\text{in}} = \sum I_{\text{out}} \qquad 0 = \sum \Delta V_i$$

$$\tau = RC \qquad I(t) = I_0 e^{-t/\tau}$$

$$V_d(t) = V_0 e^{-t/\tau} \qquad V_c(t) = V_0(1 - e^{-t/\tau})$$

$$R_s = R_1 + R_2 + \cdots \qquad 1/R_p = 1/R_1 + 1/R_2 + \cdots$$

Magnetic fields and forces

$$\Delta B = \frac{\mu_0}{4\pi}\frac{I\Delta x\sin\theta}{r^2} \qquad B_{\text{wire}} = \frac{\mu_0 I}{2\pi s}$$

$$B_{\text{loop}} = \frac{\mu_0 I}{2a} \qquad B_{\text{sol}} = \mu_0 n I$$

$$n = N/L \qquad \mathbf{B}_{\text{axis}} = \frac{\mu_0}{4\pi}\frac{2\mathbf{m}}{d^3}$$

$$m = IA \qquad \tau = mB\sin\theta$$

$$U = -mB\cos\theta$$

$$F = |q|vB\sin\alpha \qquad F = I\ell B\sin\alpha$$

$$r = mv/(qB) \qquad f = qB/(2\pi m)$$

Electrodynamics

$$\mathcal{E} = -\frac{\Delta\Phi}{\Delta t} \qquad \Phi = AB\cos\theta$$

$$\mathcal{E}_m = v\ell B$$

Mechanics

$$v = v_0 + at \qquad x = x_0 + v_0 t + at^2/2$$

$$v^2 = v_0^2 + 2a(x - x_0) \qquad a_c = v^2/r$$

$$K = mv^2/2 \qquad W = F_x\,\Delta x = -\Delta U$$

Miscellaneous

$$\sin\theta = \frac{\text{opp}}{\text{hyp}} \quad \cos\theta = \frac{\text{adj}}{\text{hyp}} \quad \tan\theta = \frac{\text{opp}}{\text{adj}}$$

$$a^2 + b^2 = c^2 \;;\; a^2 + b^2 - 2ab\cos\gamma = c^2$$

$$\text{Sphere:} \quad A = 4\pi r^2 \quad V = (4/3)\pi r^3$$

$$\text{Circle:} \quad C = 2\pi r \quad A = \pi r^2$$

$$ax^2 + bx + c = 0 \implies x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\text{Charge} : \text{C}$$

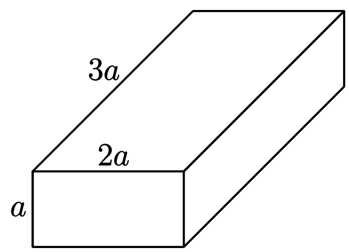
$$\text{Electric field} : \text{N/C} = \text{V/m}$$

$$\text{Electric potential} : \text{V} = \text{J/C}$$

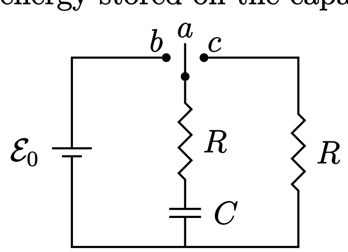
$$\text{Capacitance} : \text{F} = \text{C/V}$$

$$\text{M} = 10^6, \text{k} = 10^3, \text{m} = 10^{-3}, \mu = 10^{-6}$$

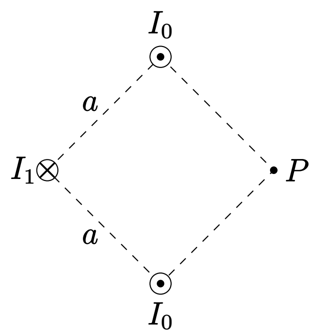
1) (25 points) A conducting material of resistivity ρ is formed into a rectangular block of side lengths a, $2a$, and $3a$, as shown below. A potential difference V is applied across one of the block's three pairs of parallel faces so that the power dissipation P is *maximized*. Find P.



2) (25 points) The capacitor in the circuit shown below is initially uncharged and the switch is in position a. At time $t = 0$, the switch is flipped to position b. At time $t = t_0$, the switch is flipped to position c. At time $t = 2t_0$, the switch is returned to position a. At time $t = 2\,t_0$, what is the energy stored on the capacitor?



3) (25 points) Three parallel infinite line currents, each perpendicular to the page, pass through the vertices of a square of side length a, shown below. Given I_0 and a, find I_1 such that the magnetic field vanishes at observation point P.



4) (25 points) A conducting wire in the shape of 45°-45°-90° triangle is in a uniform magnetic field, directed out-of-the-page with magnitude B_0. The triangle's 90° corner remains fixed at the origin, as shown. At time t, the distance between the origin and the hypotenuse is equal to vt, so that the hypotenuse is traveling with speed v. Assuming the wire's resistance per unit length is equal to λ_0, use any method to find the magnitude and direction of current $I(t)$ at time t.