PHYSICS 208 EXAM III: Fall 1999
Formula/Information Sheet

- Basic constants:

Gravitational acceleration on Earth's surface	g	=	9.8 m/sec^2
Permittivity of free space	ϵ_0	=	8.8542×10^{-12} C^2/N·m^2 [$k = 1/4\pi\epsilon_0 = 8.9875 \times 10^9$ N·m^2/C^2]
Permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ T·m/A [$k_m = \mu_0/4\pi = 10^{-7}$ Wb/A·m]
Elementary charge	e	=	1.60×10^{-19} C
Unit of energy: electron volt	1 eV	=	1.60×10^{-19} J
Unit of energy: kilowatt-hour	1 kWh	=	3.6×10^6 J
Planck's Constant	h	=	6.626×10^{-34} J sec

- Properties of some particles:

Particle	Mass [kg]	Charge [C]
Proton	1.67×10^{-27}	$+1.60 \times 10^{-19}$
Electron	9.11×10^{-31}	-1.60×10^{-19}
Neutron	1.67×10^{-27}	0

- Some indefinite integrals:

$$\int \frac{dx}{x} = \ln x \qquad \int \frac{dx}{a+bx} = \frac{1}{b}\ln(a+bx)$$

$$\int \frac{dx}{(x^2+a^2)^{3/2}} = \frac{x}{a^2\sqrt{x^2+a^2}} \qquad \int \frac{x\,dx}{(x^2+a^2)^{3/2}} = -\frac{1}{\sqrt{x^2+a^2}}$$

$$\int \frac{dx}{\sqrt{x^2 \pm a^2}} = \ln\left(x + \sqrt{x^2 \pm a^2}\right) \qquad \int \frac{x\,dx}{\sqrt{x^2 \pm a^2}} = \sqrt{x^2 \pm a^2}$$

Coulomb's law	(q at $\vec{r}_1$, q' at $\vec{r}_2$)	$\lvert\vec{F}\rvert$	$= k\,\dfrac{\lvert q_1 q_2\rvert}{\lvert\vec{r}_2 - \vec{r}_1\rvert^2}$
Electric field [N/C = V/m]	(q at $\vec{r}'$, observer at $\vec{r}$, $\vec{R} \equiv \vec{r}' - \vec{r}$)	$\vec{E}(\vec{r})$	$= k\,\dfrac{q}{R^2}\,\hat{R}$
	(group of charges)	$\vec{E}$	$= \sum \vec{E}_i = k \sum \dfrac{q_i}{R_i^2}\,\hat{R}_i$
	(continuous charge distribution)	$\vec{E}$	$= k \int \dfrac{dq}{R^2}\,\hat{R}$
line charge λ		$\lvert\vec{E}\rvert$	$= \frac{2k\lvert\lambda\rvert}{r}$
sheet charge σ		$\lvert\vec{E}\rvert$	$= 2\pi k\lvert\sigma\rvert$
Electric force [N]	(on q subject to $\vec{E}$)	$\vec{F}$	$= q\,\vec{E}$

Electric flux	(small area ΔA_i, outward normal $\hat{n}_i$)	$\Delta\Phi_i$	$= \vec{E}_i \cdot \hat{n}_i \Delta A_i = E_i\,\Delta A_i\,\cos\theta_i$
	(through an entire surface area)	$\Phi_{surface}$	$= \lim_{\Delta A \to 0} \sum \Delta\Phi_i = \int \vec{E} \cdot \hat{n}\,dA$
Gauss' law	(through a closed surface area)	Φ_{closed}	$\equiv \oint \vec{E} \cdot \hat{n}\,dA = 4\pi k Q_{enc}$
Conductor		$(\vec{E} \cdot \hat{n})_{out}$	$= 4\pi k \sigma_S$

Electric potential [Volt = J/C]	(definition, step-length ds along $\hat{s}$)	ΔV	$= V_B - V_A = -\int_A^B \vec{E} \cdot \hat{s}\,ds$
	($\vec{E}$ = constant)	ΔV	$= -\vec{E} \cdot (\vec{r}_B - \vec{r}_A)$
	(point charge q at $\vec{r}'$)	$V(\vec{r})$	$= k\,\dfrac{q}{\lvert\vec{R}\rvert} \quad (V(\infty) = 0)$
	(group of charges, $\vec{R}_i \equiv \vec{r} - \vec{r}_i$)	$V(\vec{r})$	$= \sum V_i(\lvert\vec{R}_i\rvert) = k \sum \dfrac{q_i}{\lvert\vec{R}_i\rvert} \quad (V_i(\infty) = 0)$
	(continuous charge distribution)	$V(\vec{r})$	$= k \int \dfrac{dq}{\lvert\vec{R}\rvert} \quad (V(\infty) = 0)$
Electric potential energy [J]	(definition)	ΔU	$= U_B - U_A = -q_0 \int_A^B \vec{E} \cdot \hat{s}\,ds$
			$= q_0\,(V_B - V_A)$
$\vec{E}$ from V		$\vec{E}$	$= -\vec{\nabla} V \quad (\vec{\nabla}$ = gradient operator)
Electric potential energy of two-charge system		U_{12}	$= k\,\dfrac{q_1 q_2}{\lvert\vec{r}_1 - \vec{r}_2\rvert}$

Capacitance [Farad = C/V]	(definition)	$C = \frac{Q}{\Delta V}$
Sphere of radius R		$C = \frac{R}{k}$
Parallel plates of area A and separation d		$C = \frac{A}{4\pi k d}$
Effect of dielectric on electric field		$E = E_0/\kappa$
Electrostatic potential energy [J] stored in capacitance		$U_E(t) = \frac{1}{2}\frac{Q(t)^2}{C}$
Electric energy per unit volume		$u_{electric} = \epsilon_0 E^2/2 = E^2/8\pi k$
Electric dipole moment ($2a$ = separation between two charges)		$\lvert\vec{p}\rvert = 2aq$
Torque on electric dipole moment		$\vec{\tau} = \vec{p} \times \vec{E}$
Potential energy of an electric dipole moment		$U = -\vec{p} \cdot \vec{E}$

Current [A]	(definition)	I	$\equiv$	$\frac{d\,Q(t)}{d\,t}$
	with motion of charges	I	$=$	$nqv_d A$
Current density [A/m^2]		J	$=$	$\frac{I}{A}$ (where $I = \int \vec{J} \cdot \hat{n}\, dA$)
Resistivity [Ω·m]		ρ	$=$	$\frac{\lvert\vec{E}\rvert}{\lvert\vec{J}\rvert}$
Resistance [Ω]	(definition)	R	$\equiv$	$\frac{\Delta V}{I}$
	for uniform cross-sectional area A	R	$=$	$\rho\frac{\ell}{A}$
Current provided by Emf E [V]	internal resistance r	I	$=$	$(\mathcal{E} - \Delta V)/r$
Power provided by emf E [J/s]		$\mathcal{P}$	$=$	$\mathcal{E} I$
Energy loss rate by R [J/s]		$\mathcal{P}$	$=$	$I^2 R = (\Delta V)^2/R = I(\Delta V)$
Time constant in RC circuit [s]		τ_{RC}	$=$	RC

Magnetic force [N]	on pole q_m	$\vec{F}$	$= q_m \vec{B}$
Magnetic field [N]	due to pole Q_m	$\lvert\vec{B}\rvert$	$= \frac{k_m \lvert Q_m\rvert}{R^2}$
Magnetic moment [A·m^2 or J/T]	poles $\pm q_m$ separated by l	$\lvert\vec{\mu}\rvert$	$= q_m l$
Torque [N·m]	on a magnet	$\vec{\tau}$	$= \vec{\mu} \times \vec{B}$
Energy [N·m]	of a magnet	U	$= -\vec{\mu} \cdot \vec{B}$
sheet charge $\sigma_m = q_m/A$		$\lvert\vec{B}\rvert$	$= 2\pi k_m \lvert\sigma_m\rvert$

Magnetic force [N]	on charge q	$\vec{F}$	$=$	$q\,\vec{v} \times \vec{B}$
	on current-carrying conductor	$\vec{F}$	$=$	$\int I d\vec{s} \times \vec{B}$
cyclotron frequency [radians/sec]	charge q, mass m	ω	$=$	$\lvert q\rvert\lvert\vec{B}\rvert/m$
Magnetic moment [A·m^2 or J/T]		$\vec{\mu}$	$=$	$I\hat{n}A$
Torque [N·m]	on a current loop	$\vec{\tau}$	$=$	$\vec{\mu} \times \vec{B}$
Ampere's law		$\oint \vec{B} \cdot d\vec{s}$	$=$	$\mu_0 I = 4\pi k_m I$
Biot-Savart law		$d\vec{B}$	$=$	$k_m \frac{I\, d\vec{s} \times \hat{R}}{R^2}$
Magnetic field [T]	a long straight wire	$\lvert\vec{B}\rvert$	$=$	$\mu_0 I/(2\pi a)$
	inside a toroid	$\lvert\vec{B}\rvert$	$=$	$\mu_0 NI/(2\pi r)$
	inside a solenoid	$\lvert\vec{B}\rvert$	$=$	$\mu_0 NI/\ell$
	a straight wire segment	$\lvert\vec{B}\rvert$	$=$	$k_m I(\cos\theta_1 - \cos\theta_2)/a$
	a circular arc (radius R)	$\lvert\vec{B}\rvert$	$=$	$k_m I\theta/R$
Displacement current [A]	(definition)	I_d	$\equiv$	$\epsilon_0 \frac{d\Phi_E}{dt} = \epsilon_0 \frac{d}{dt}\int \vec{E} \cdot \hat{n}\, dA$
Ampere-Maxwell law		$\oint \vec{B} \cdot d\vec{s}$	$=$	$\mu_0 (I + I_d)$
Faraday's Law		$\mathcal{E}$	$=$	$-\frac{d\,\Phi_B}{d\,t}$
Mutual Inductance [H]	(definition)	M_{21}	$=$	$N_2 \Phi_{21}/I_1$
Electromotive force induced by mutual induction [V]		$\mathcal{E}_2$	$=$	$-M_{21}\frac{d\,I_1}{d\,t}$
Self Inductance [H]	(definition)	L	$=$	$N\Phi_B/I$
Self Induced electromotive force [V]		$\mathcal{E}$	$=$	$-L\frac{d\,I}{d\,t}$
Magnetic energy per unit volume		$u_{magnetic}$	$=$	$B^2/2\mu_0 = B^2/8\pi k_m$
Magnetic energy stored in L [J]		$U_B(t)$	$=$	$\frac{1}{2}LI(t)^2$
Time constant in LR circuits [s]		τ_{LR}	$=$	L/R
Angular frequency of LC circuit [rad/sec]		ω	$=$	$\sqrt{\frac{1}{LC}}$