PHYSICS 208 Exam 3/Final Exam: Spring 2004
Formula/Information Sheet

- Basic constants:

Gravitational acceleration	g	=	9.8 m/sec^2
Permittivity of free space	ϵ_0	=	$8.8542 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$ [$k = 1/4\pi\epsilon_0 = 8.9875 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$]
Permeability of free space	μ_0	=	$4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}$ [$k_m = \mu_0/4\pi = 10^{-7} \text{ Wb/A}\cdot\text{m}$]
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:

$$\int \frac{dx}{x} = \ln x \qquad \int \frac{dx}{a+bx} = \frac{1}{b}\ln(a+bx)$$
$$\int \frac{dx}{(x^2+a^2)^{3/2}} = \frac{x}{a^2\sqrt{x^2+a^2}} \qquad \int \frac{x\,dx}{(x^2+a^2)^{3/2}} = -\frac{1}{\sqrt{x^2+a^2}}$$
$$\int \frac{dx}{\sqrt{x^2\pm a^2}} = \ln\left(x+\sqrt{x^2\pm a^2}\right) \qquad \int \frac{x\,dx}{\sqrt{x^2\pm a^2}} = \sqrt{x^2\pm a^2}$$

- Basic equations for Electromagnetism:

Maxwell equations:
$$\oint \vec{E}\cdot d\vec{l} = -\frac{d\phi_B}{dt}$$
$$\oint \vec{B}\cdot d\vec{l} = \mu_0\left(i+\epsilon_0\frac{d\phi_E}{dt}\right)$$
$$\oint \vec{E}\cdot d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$$
$$\oint \vec{B}\cdot d\vec{A} = 0$$

- Basic Equations for Waves, Interference and Diffraction:

Wave Equation	$\frac{\partial^2 f(x,t)}{\partial x^2}$	=	$\frac{1}{v^2}\frac{\partial^2 f(x,t)}{\partial t^2}$
Plane EM wave traveling in the $+x$ direction	$E(x,t)$	=	$E_m \sin(kx-\omega t)$
	$B(x,t)$	=	$B_m \sin(kx-\omega t)$
Speed of an EM wave [m/s]	c	=	$\frac{1}{\sqrt{\mu_0\epsilon_0}} = \frac{E_m}{B_m} = \frac{E(x,t)}{B(x,t)}$
Wave length of an EM wave [m]	λ	=	$\frac{c}{f}$
Wave number of an EM wave	k	=	$\frac{2\pi}{\lambda}$
Poynting vector [J/s·m^2]	$\vec{S}$	=	$\frac{1}{\mu_0}\vec{E}\times\vec{B}$
Time-averaged S [J/s·m^2]	S_{ave}	=	$\frac{E_m B_m}{2\mu_0}$
Intensity of an EM wave [J/s·m^2]	I	=	S_{ave}
Total energy of an EM wave [J]	U	=	$I\ A\ t$
Total momentum of an EM wave	$\lvert\vec{p}\rvert$	=	$\frac{U}{c}$
Law of Reflection	θ_{incident}	=	$\theta_{\text{reflected}}$
Snell's Law	$n_1\sin(\theta_1)$	=	$n_2\sin(\theta_2)$
Lens Equation	$\frac{1}{f}$	=	$\frac{1}{d_o}+\frac{1}{d_i}$
Lens Maker's Equation	$\frac{1}{f}$	=	$(n-1)(\frac{1}{R_1}-\frac{1}{R_2})$
Magnification	M	=	$\frac{h_i}{h_o} = \frac{-d_i}{d_o}$
Double Slit Constructive Int.	$d\sin(\theta)$	=	$m\lambda$
Double Slit Destructive Int.	$d\sin(\theta)$	=	$(m+\frac{1}{2})\lambda$
Intensity Maxima	I_θ	=	$I_o\cos^2(\delta/2)$
	δ	=	$\frac{2\pi}{\lambda}\sin(\theta)$
Energy of an EM Wave (photon)	E	=	hf
Single Slit Dest. Int.	$\sin(\theta)$	=	$\frac{m\lambda}{a}$

- Basic equations for Magnetism and Induction:

Magnetic force [N]	on charge q	$\vec{F}$	$=$	$q\,\vec{v}\times\vec{B}$
	on current-carrying conductor	$\vec{F}$	$=$	$\int I d\vec{l}\times\vec{B}$
Magnetic moment [A·m^2 or J/T]		$\vec{\mu}$	$=$	$I\vec{A}$
Torque [N·m]	on a current loop	$\vec{\tau}$	$=$	$\vec{\mu}\times\vec{B}$
Ampere's law		$\oint \vec{B}\cdot d\vec{l}$	$=$	$\mu_0\,I$
Biot-Savart law		$d\vec{B}$	$=$	$k_m\,\frac{I\,d\vec{l}\times\hat{r}}{r^2}$
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	$\equiv$	$\epsilon_0\frac{d\Phi_E}{dt}$
Ampere-Maxwell law		$\oint \vec{B}\cdot d\vec{s}$	$=$	$\mu_0\,(I+I_d)$
Faraday's Law		$\mathcal{E}$	$=$	$-\frac{d\,\Phi_{\rm m}}{d\,t}$
Self Inductance [H]	(definition)	L	$=$	$\frac{N\Phi_{\rm m}}{I}$
Self Induced electromotive force [V]		$\mathcal{E}$	$=$	$-L\frac{d\,I}{d\,t}$
Mutual Inductance [H]	(definition)	M_{21}	$=$	$N_2\frac{\Phi_{21}}{I_1}$
Electromotive force induced by mutual induction [V]		$\mathcal{E}_2$	$=$	$-M_{21}\frac{d\,I_1}{d\,t}$
Magnetic field energy density		$u_{magnetic}$	$=$	$\frac{1}{2\,\mu_o}B^2$
Magnetic energy stored in L [J]		$U_B(t)$	$=$	$\frac{1}{2}LI(t)^2$
Time constant in LR circuits [s]		τ_{LR}	$=$	$\frac{L}{R}$
Energizing an LR circuit [I(t)]		$I(t)$	$=$	$I_f(1-e^{-tR/L})$
De-energizing an LR circuit [I(t)]		$I(t)$	$=$	$I_o e^{-tR/L}$
Angular frequency of LC circuit [rad/sec]		ω	$=$	$\sqrt{\frac{1}{LC}}$

- Basic equations for Electric Fields:

Coulomb's law		$\lvert\vec{F}\rvert$	=	$k\,\dfrac{\lvert q_1\rvert\lvert q_2\rvert}{r^2}$
Electric field [N/C = V/m]	(point charge q)	$\vec{E}(r)$	=	$k\,\dfrac{q}{r^2}\,\hat{r}$
		($\hat{r}$ = unit vector radially from q)		
	(group of charges)	$\vec{E}$	=	$\sum \vec{E}_i \;=\; k \sum \dfrac{q_i}{r_i^2}\,\hat{r}_i$
	(continuous charge distribution)	$\vec{E}$	=	$k \displaystyle\int \dfrac{dq}{r^2}\,\hat{r}$
		($\hat{r}$ = unit vector radially from dq)		
Electric force [N]	(on q in $\vec{E}$)	$\vec{F}$	=	$q\,\vec{E}$

Electric flux	(through a small area ΔA_i)	$\Delta\Phi_i$	=	$\vec{E}_i \cdot \Delta\vec{A}_i \;=\; E_i\,\Delta A_i\,\cos\theta_i$
	(through an entire surface area)	$\Phi_{surface}$	=	$\lim\limits_{\Delta A\to 0} \sum \Delta\Phi_i = \displaystyle\int \vec{E}\cdot d\vec{A}$
Gauss' law	(through a closed surface area)	Φ_{closed}	$\equiv$	$\displaystyle\oint \vec{E}\cdot d\vec{A} = \dfrac{Q_{in}}{\epsilon_0}$

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

Capacitance [F]	(definition)	C	$\equiv$	$\dfrac{Q}{\lvert\Delta V\rvert}$
	(parallel-plate capacitance)	C	=	$\kappa\dfrac{\epsilon_0 A}{d}$
Electrostatic potential energy [J] stored in capacitance		$U_E(t)$	=	$\dfrac{1}{2}\,\dfrac{Q(t)^2}{C}$
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_dA
Current density [A/m^2]		J	=	$\frac{I}{A}$ (where $I \;=\; \int \vec{J}\cdot\vec{n}\,dA$)
Resistivity [Ω·m]		ρ	=	$\frac{\lvert\vec{E}\rvert}{\lvert\vec{J}\rvert}$
Resistance [Ω]	(definition)	R	$\equiv$	$\frac{V}{I}$
	for uniform cross-sectional area A	R	=	$\rho\frac{\ell}{A}$
Energy loss rate on R [J/s]		P	=	$I^2R = V^2/R = IV$
Time constant in RC circuit [s]		τ_{RC}	=	RC
Charging an RC circuit [q(t)]		$q(t)$	=	$q_f(1-e^{-t/RC})$
Discharging an RC circuit [q(t)]		$q(t)$	=	$q_o e^{-t/RC}$