PHYSICS 208 EXAM II: Spring 2004
Formula/Information Sheet

- Basic constants:

Gravitational acceleration	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

- 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 $\quad |\vec{F}| = k\,\dfrac{|q_1||q_2|}{r^2}$

Electric field [N/C = V/m] (point charge q) $\quad \vec{E}(r) = k\,\dfrac{q}{r^2}\,\hat{r}$

($\hat{r}$ = unit vector radially from q)

(group of charges) $\quad \vec{E} = \sum \vec{E}_i = k \sum \dfrac{q_i}{r_i^2}\,\hat{r}_i$

(continuous charge distribution) $\quad \vec{E} = k \displaystyle\int \frac{dq}{r^2}\,\hat{r}$

($\hat{r}$ = unit vector radially from dq)

Electric force [N] (on q in $\vec{E}$) $\quad \vec{F} = q\,\vec{E}$

Electric flux (through a small area ΔA_i) $\quad \Delta\Phi_i = \vec{E}_i \cdot \Delta\vec{A}_i = E_i\,\Delta A_i\,\cos\theta_i$

(through an entire surface area) $\quad \Phi_{surface} = \displaystyle\lim_{\Delta A \to 0} \sum \Delta\Phi_i = \int \vec{E}\cdot d\vec{A}$

Gauss' law (through a closed surface area) $\quad \Phi_{closed} \equiv \displaystyle\oint \vec{E}\cdot d\vec{A} = \frac{Q_{in}}{\epsilon_0}$

Electric potential [V = J/C] (definition) $\quad \Delta V = V_B - V_A = -\displaystyle\int_A^B \vec{E}\cdot d\vec{s}$

($\vec{E}$ = constant) $\quad \Delta V = -\vec{E}\cdot(\vec{r}_B - \vec{r}_A)$

(point charge q) $\quad V(r) = k\,\dfrac{q}{r}$ (with $V(\infty) = 0$)

(group of charges) $\quad V(\vec{r}) = \sum V_i(|\vec{r} - \vec{r}_i|) = k \sum \dfrac{q_i}{|\vec{r} - \vec{r}_i|}$

($V_i(\infty) = 0$)

(continuous charge distribution) $\quad V(\vec{r}) = k \displaystyle\int \frac{dq\,'}{|\vec{r} - \vec{r}\,'|}$

($V(\infty) = 0$)

Electric potential energy [J] (definition) $\quad \Delta U = U_B - U_A = -q_0 \displaystyle\int_A^B \vec{E}\cdot d\vec{s} = q_0\,(V_B - V_A)$

$\vec{E}$ from V $\quad \vec{E} = -\vec{\nabla} V$

($\vec{\nabla}$ = gradient operator)

Electric potential energy of two-charge system $\quad U_{12} = k\,\dfrac{q_1 q_2}{r_{12}}$

Capacitance [F]	(definition)	C	$\equiv$	$\frac{Q}{\lvert\Delta V\rvert}$
	(parallel-plate capacitance)	C	$=$	$\kappa \frac{\epsilon_0 A}{d}$
Electrostatic potential energy [J] stored in capacitance		$U_E(t)$	$=$	$\frac{1}{2}\frac{Q(t)^2}{C}$
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	$=$	$nqv_d A$
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	$=$	$I^2 R = V^2/R = IV$
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)]		$q(t)$	$=$	$q_o e^{-t/RC}$

Magnetic force [N]	on charge q	$\vec{F}$	$=$	$q\,\vec{v} \times \vec{B}$
	on current-carrying conductor	$\vec{F}$	$=$	$I \int d\vec{s} \times \vec{B}$
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		$\oint \vec{B} \cdot d\vec{s}$	$=$	$\mu_0 I$
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	$\equiv$	$\epsilon_0 \frac{d\Phi_E}{dt}$
Ampere-Maxwell law		$\oint \vec{B} \cdot d\vec{s}$	$=$	$\mu_0 (I + I_d)$