PHYS 2012
Fundamental Equations and Important Results and Constants

you need to know — and know how to use.

Chap. 21

Coulomb's Law for point electric charges: $F_{12} = \frac{1}{4\pi\varepsilon_o}\frac{|q_1 q_2|}{r^2}$

$\frac{1}{4\pi\varepsilon_o} = 8.99 \times 10^9\,\mathrm{Nm^2/C^2} \qquad e = 1.60 \times 10^{-19}\,\mathrm{C}$

Chap. 22

Field due to a point charge: $\vec{E} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}\hat{r}$

Electric field due to a continuous charge distribution: $\vec{E} = \frac{1}{4\pi\varepsilon_o}\int \frac{dq}{r^2}\hat{r}$

Infinite line charge: $E(r) = \frac{1}{2\pi\varepsilon_o}\frac{\lambda}{r}$ Infinite sheet charge: $E = \frac{\sigma}{2\varepsilon_o}$

Force on an electric charge q in an electric field $\vec{E}$ due to other charges: $\vec{F} = q\vec{E}$

Electric dipoles: $|\vec{p}| = qd \qquad \vec{p} = \sum q_i \vec{r}_i \qquad \vec{\tau} = \vec{p} \times \vec{E} \qquad U_{dip} = -\vec{p}\cdot\vec{E}$

Chap. 24

Electric potential: $\Delta V = V_f - V_i = -\int_i^f \vec{E}\cdot d\vec{s}$

Electric potential created by a point charge, q: $V(r) = \frac{1}{4\pi\varepsilon_o}\frac{q}{r}$

$E_x = -\frac{\partial V}{\partial x},\ E_y = -\frac{\partial V}{\partial y},\ E_z = -\frac{\partial V}{\partial z}$

Electric potential energy of a charge, q_0 in an electric field: $U(\vec{r}) = q_0 V(\vec{r})$

Electric potential energy of a pair of charges: $U(r) = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r}$

Chap. 23

Electric flux and Gauss's Law:

$$\Phi = \int \vec{E}\cdot d\vec{A} \qquad \varepsilon_o \oint \vec{E}\cdot d\vec{A} = q_{\mathrm{enclosed}}$$

Chap. 25

Capacitance: $q = CV$ Parallel plates $C = \frac{\kappa\varepsilon_o A}{d}$
Parallel capacitors: $C_{eq} = C_1 + C_2 + \ldots$
Series capacitors: $C_{eq}^{-1} = C_1^{-1} + C_2^{-1} + \ldots$
Energy stored and energy density: $U = \frac{1}{2}CV^2$ $u = \frac{1}{2}\varepsilon_o E^2$

Chap. 26

Current and current density:

$$i = \frac{dq}{dt} \qquad J = i/A \qquad i = \int \vec{J} \cdot d\vec{A}$$

Resistance and Ohm's law: $R = V/i$ $R = \rho L/A$ $\vec{J} = \frac{1}{\rho}\vec{E}$
Power: $P = Vi$

Chap. 27

EMF: $\mathcal{E} = \frac{dW}{dq}$
Series resistances: $R_{eq} = R_1 + R_2 + \ldots$
Parallel resistances $R_{eq}^{-1} = R_1^{-1} + R_2^{-1} + R_3^{-1} \ldots$
Kirchhoff's Circuit Rules

$$\sum_{in} i = \sum_{out} i \qquad \sum_{closed\ loop} \Delta V = 0$$

Chap. 28

Magnetic force: $\vec{F} = q\vec{v} \times \vec{B}$
Circular motion of a charge in a uniform field: $qvB = m\frac{v^2}{r}$
Force on a current-carrying wire: $\vec{F} = i\,\vec{L} \times \vec{B}$,
or for a short segment: $\vec{F} = i\,d\vec{L} \times \vec{B}$

Magnetic dipole moment of a single current loop: $\vec{\mu} = i\vec{A}$
Magnetic torque on a dipole: $\vec{\tau} = \vec{\mu} \times \vec{B}$, Magnetic dipole potential energy: $U(\theta) = -\vec{\mu} \cdot \vec{B}$.

Chap. 29

$\mu_o = 4\pi \times 10^{-7}$ Tm/A

Biot-Savart Law:

$$d\vec{B} = \frac{\mu_o}{4\pi}\frac{i\,d\vec{s} \times \hat{r}}{r^2}$$

Ampere's Law:

$$\oint \vec{B} \cdot d\vec{s} = \mu_o i_{enc}$$

Know how to use the Biot-Savart law to get the magnetic field at the center of a circular current loop:
$B = \frac{\mu_o i}{2R}$
Know how to use Ampere's law to get the magnetic field of a long wire:
$B = \frac{\mu_o i}{2\pi r}$
Magnetic field due to a straight solenoid of N turns and length L:
$B = \mu_o n i$, with $n = N/L$

Chap. 30

Magnetic flux:

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

Faraday's law:

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = \oint \vec{E} \cdot d\vec{s}$$

Self inductance:

$$N\Phi_B = Li \qquad \mathcal{E} = -L\frac{di}{dt} \qquad U_B = \frac{1}{2}Li^2$$

Mutual inductance:

$$N_2\Phi_{21} = Mi_1 \qquad \mathcal{E}_2 = -M\frac{di_1}{dt}$$

Chap. 32

The Ampere-Maxwell law:

$$\oint \vec{B} \cdot d\vec{s} = \mu_o(i_{enc} + i_d) \quad \text{with} \quad i_d = \varepsilon_o\frac{d\Phi_E}{dt}$$

Gauss's Law for magnetic fields: $\oint \vec{B} \cdot d\vec{A} = 0$.

Chap. 33

Traveling E-M plane wave: $\vec{E}(x,t) = \vec{E}_m \sin(kx - \omega t)$
with $k = 2\pi/\lambda$ and $\omega = 2\pi f$, and $\lambda f = c$
Associated $B_m = E_m/c$
Poynting vector: $\vec{S} = \frac{1}{\mu_o}\vec{E} \times \vec{B}$ Time averaged: $\langle S \rangle = I = E_m^2/(c\mu_o)$
Isotropic source of power P produces $I = \frac{P}{4\pi r^2}$
Radiation force: $F_{rad} = \frac{(2)IA}{c}$ The (2) is present for reflecting surfaces.
Radiation pressure $p_{rad} = F_{rad}/A = \frac{(2)I}{c}$
$I = I_o/2$ unpolarized light passing through a polarizer
$I = I_o \cos^2\theta$ linearly polarized light passing through a polarizer Snell's law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$
Critical angle of incidence for total internal reflection implies $\theta_2 = 90°$

Chap. 34

$1/p + 1/i = 1/f \quad m = h_i/h_o = -i/p \quad m_\theta = P_n/f$
$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad f = \frac{r}{2}$

Chap. 35

$v = c/n$, $\lambda_n = \lambda/n$, $d\sin\theta = n\lambda$ constructive, $d\sin\theta = (n + \frac{1}{2})\lambda$ destructive.

Formulas provided at final exam:

Circles and spheres: $C = 2\pi r$ $A = \pi r^2$ $A = 4\pi r^2$ $V = \frac{4\pi}{3} r^3$
$\frac{1}{4\pi\varepsilon_o} = 8.99 \times 10^9$ [units=?] $\mu_o = 4\pi \times 10^{-7}$ [units=?]
$c^2 = 1/(\varepsilon_o \mu_o)$, $c = 3.00 \times 10^8$ m/s

$k = \frac{2\pi}{\lambda}$ $\omega = 2\pi f$ $\lambda f = c$
$v = c/n$, $\lambda_n = \lambda/n$, $d \sin\theta = n\lambda$ constructive, $d \sin\theta = (n + \frac{1}{2})\lambda$ destructive.

$\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r}$

$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $f = \frac{r}{2}$ $m = -i/p$ $m_\theta = 25cm/f$
$I = I_o/2$ $I = I_o \cos^2\theta$ $\langle S \rangle = I = E_m^2/(2c\mu_o)$ $B_m = E_m/c$ $p_{rad} = \frac{[2]I}{c}$

$i_d = \varepsilon_o \frac{d\Phi_E}{dt}$
$N\Phi_B = Li$ $\mathcal{E} = -L\frac{di}{dt}$ $U = \frac{1}{2}Li^2$ $u_B = \frac{B^2}{2\mu_o}$

$N_2\Phi_{21} = Mi_1$ $\mathcal{E}_2 = -M\frac{di_1}{dt}$

$d\vec{F} = i\, d\vec{L} \times \vec{B}$ $d\vec{B} = \frac{\mu_o}{4\pi} \frac{i\, d\vec{s} \times \hat{r}}{r^2}$

$B = \mu_o n i$ $B = \frac{\mu_o i}{2\pi r}$ $B = \frac{\mu_o i}{2R}$ $\vec{\mu} = i\vec{A}$ $\vec{\tau} = \vec{\mu} \times \vec{B}$ $U(\theta) = -\vec{\mu} \cdot \vec{B}$

$i(t) = i_f(1 - e^{-Rt/L})$ $V_L(t) = V_b e^{-Rt/L}$
$i(t) = i_o e^{-t/RC}$ $V_C(t) = V_b(1 - e^{-t/RC})$

$\vec{J} = \frac{1}{\rho}\vec{E}$ $\vec{J} = nq\vec{v}$

$U = \frac{1}{2}CV^2$ $u = \frac{1}{2}\varepsilon_o E^2$

$\Delta V = V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}$ $V(r) = \frac{1}{4\pi\varepsilon_o}\frac{q}{r}$ $E_x = -\frac{\partial V}{\partial x}$

$E(r) = \frac{1}{2\pi\varepsilon_o}\frac{\lambda}{r}$ $E = \frac{\sigma}{2\varepsilon_o}$ $p = qd$ $\vec{\tau} = \vec{p} \times \vec{E}$ $U = -\vec{p} \cdot \vec{E}$

Prominent equations NOT provided:

$$F_{12} = \frac{1}{4\pi\varepsilon_o}\frac{|q_1 q_2|}{r^2}$$

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

$$\varepsilon_o \oint \vec{E} \cdot d\vec{A} = q_{\text{enclosed}}$$

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = \oint \vec{E} \cdot d\vec{s}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_o(i_{enc} + \varepsilon_o \frac{d\Phi_E}{dt})$$

$$\oint \vec{B} \cdot d\vec{A} = 0$$

$e = 1.60 \times 10^{-19}\,\mathbf{C}$ $\quad \vec{E} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}\hat{r}$ $\quad \vec{E} = \frac{1}{4\pi\varepsilon_o}\int \frac{dq}{r^2}\hat{r}$

$U(r) = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r}$ $\quad U = qV$

$q = CV$ $\quad C = \frac{\kappa\varepsilon_o A}{d}$ $\quad C_{eq} = C_1 + C_2 + \ldots$ $\quad C_{eq}^{-1} = C_1^{-1} + C_2^{-1} + \ldots$

$i = \frac{dq}{dt}$ $\quad i = \int \vec{J} \cdot d\vec{A}$ $\quad J = i/A$

$R = V/i$ $\quad R = \rho L/A$ $\quad P = Vi$

$R_{eq} = R_1 + R_2 + \ldots$ $\quad R_{eq}^{-1} = R_1^{-1} + R_2^{-1} + R_3^{-1} \ldots$

$\sum i_{in} = \sum i_{out}$ $\quad \sum \Delta V = 0$

$\vec{S} = \frac{1}{\mu_o}\vec{E} \times \vec{B}$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\quad 1/p + 1/i = 1/f$