Formula Sheet for LSU Physics 2113, Third Exam, Spring '15

- **Constants, definitions:**

$g = 9.8\,\frac{\mathrm{m}}{\mathrm{s}^2}$ | $R_{Earth} = 6.37 \times 10^6\,\mathrm{m}$ | $M_{Earth} = 5.98 \times 10^{24}\,\mathrm{kg}$

$G = 6.67 \times 10^{-11}\,\frac{\mathrm{m}^3}{\mathrm{kg}\cdot\mathrm{s}^2}$ | $R_{Moon} = 1.74 \times 10^6\,\mathrm{m}$ | Earth-Sun distance = 1.50×10^{11} m

$M_{Sun} = 1.99 \times 10^{30}\,\mathrm{kg}$ | $M_{Moon} = 7.36 \times 10^{22}\,\mathrm{kg}$ | Earth-Moon distance = 3.82×10^{8} m

$\epsilon_o = 8.85 \times 10^{-12}\,\frac{\mathrm{C}^2}{\mathrm{Nm}^2}$ | $k = \frac{1}{4\pi\epsilon_o} = 8.99 \times 10^9\,\frac{\mathrm{Nm}^2}{\mathrm{C}^2}$ | $e = 1.60 \times 10^{-19}\,\mathrm{C}$

$c = 3.00 \times 10^8\,\mathrm{m/s}$ | $m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$ | $1\ \mathrm{eV} = \mathrm{e}(1\mathrm{V}) = 1.60\times10^{-19}\,\mathrm{J}$

dipole moment: $\vec{p} = q\vec{d}$ | $m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$ | charge densities: $\lambda = \frac{Q}{L}$, $\sigma = \frac{Q}{A}$, $\rho = \frac{Q}{V}$

Area of a circle: $A = \pi r^2$ | Area of a sphere: $A = 4\pi r^2$ | $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T\cdot m/A}$

Area of a cylinder: $A = 2\pi r\ell$ | Volume of a cylinder: $V = \pi r^2 \ell$ | Volume of a sphere: $V = \frac{4}{3}\pi r^3$

- **Kinematics (constant acceleration):**

$v = v_o + at \qquad x - x_o = \frac{1}{2}(v_o + v)t \qquad x - x_o = v_o t + \frac{1}{2}at^2 \qquad v^2 = v_o^2 + 2a(x - x_o)$

- **Circular motion:** $F_c = ma_c = \frac{mv^2}{r}, \quad T = \frac{2\pi r}{v}, \quad v = \omega r$

- **General (work, def. of potential energy, kinetic energy):**

$K = \frac{1}{2}mv^2 \qquad \vec{F}_{\mathrm{net}} = m\vec{a} \qquad E_{\mathrm{mech}} = K + U$

$W = -\Delta U$ (by field) $\quad W_{ext} = \Delta U$ (if objects are initially and finally at rest)

- **Gravity:**

Newton's law: $|\vec{F}| = G\frac{m_1 m_2}{r^2}$ | Gravitational acceleration (planet of mass M): $a_g = \frac{GM}{r^2}$

Gravitational Field: $\vec{g} = -G\frac{M}{r^2}\hat{r} = -\frac{dV_g}{dr}$ | Gravitational potential: $V_g = -\frac{GM}{r}$

Law of periods: $T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$ | Potential Energy: $U = -G\frac{m_1 m_2}{r_{12}}$

Potential Energy of a System (more than 2 masses): $U = -\left(G\frac{m_1 m_2}{r_{12}} + G\frac{m_1 m_3}{r_{13}} + G\frac{m_2 m_3}{r_{23}} + \ldots\right)$

Gauss' law for gravity: $\oint_S \vec{g}\cdot d\vec{S} = -4\pi G M_{ins}$

- **Electrostatics:**

Coulomb's law: $|\vec{F}| = k\frac{|\,q_1\,||\,q_2\,|}{r^2}$ | Force on a charge in an electric field: $\vec{F} = q\vec{E}$

Electric field of a point charge: $|\vec{E}| = k\frac{|\,q\,|}{r^2}$

Electric field of a dipole on axis, far away from dipole: $\vec{E} = \frac{2k\vec{p}}{z^3}$

Electric field of an infinite line charge: $|\vec{E}| = \frac{2k\lambda}{r}$

Electric field at the center of uniformly charged arc of angle ϕ: $|\vec{E}| = \frac{\lambda \sin(\phi/2)}{2\pi\epsilon_0 R}$

Torque on a dipole in an $\vec{E}$ field: $\vec{\tau} = \vec{p}\times\vec{E}$, $\qquad$ Potential energy of a dipole in $\vec{E}$ field: $U = -\vec{p}\cdot\vec{E}$

- **Electric flux:** $\Phi = \int \vec{E}\cdot d\vec{A}$
- **Gauss' law:** $\epsilon_o \oint \vec{E}\cdot d\vec{A} = q_{enc}$

- **Electric field of an infinite non-conducting plane with a charge density σ:** $E = \frac{\sigma}{2\epsilon_o}$

- **Electric field of infinite conducting plane or close to the surface of a conductor:** $E = \frac{\sigma}{\epsilon_o}$

- **Electric potential, potential energy, and work:**

  $V_f - V_i = -\int_i^f \vec{E}\cdot d\vec{s}$ In a uniform field: $\Delta V = -\vec{E}\cdot\Delta\vec{s} = -Ed\cos\theta$

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

  Potential of a point charge q: $V = k\frac{q}{r}$ Potential of n point charges: $V = \sum_{i=1}^{n} V_i = k\sum_{i=1}^{n}\frac{q_i}{r_i}$

  Electric potential energy: $\Delta U = q\Delta V$ $\Delta U = -W_{\text{field}}$

  Potential energy of two point charges: $U_{12} = W_{\text{ext}} = q_2V_1 = q_1V_2 = k\frac{q_1q_2}{r_{12}}$

- **Capacitance: definition:** $q = CV$

  Capacitor with a dielectric: $C = \kappa C_{air}$ Parallel plate: $C = \varepsilon_\circ\frac{A}{d}$

  Potential Energy in Cap: $U = \frac{q^2}{2C} = \frac{1}{2}qV = \frac{1}{2}CV^2$ Energy density of electric field: $u = \frac{1}{2}\kappa\varepsilon_o|\vec{E}|^2$

  Capacitors in parallel: $C_{eq} = \sum C_i$ Capacitors in series: $\frac{1}{C_{eq}} = \sum\frac{1}{C_i}$

- **Current:** $i = \frac{dq}{dt} = \int\vec{J}\cdot d\vec{A}$, Const. curr. density: $J = \frac{i}{A}$, Charge carrier's drift speed: $\vec{v}_d = \frac{\vec{J}}{ne}$

- **Definition of resistance:** $R = \frac{V}{i}$ Definition of resistivity: $\rho = \frac{|\vec{E}|}{|\vec{J}|}$

- **Resistance in a conducting wire:** $R = \rho\frac{L}{A}$ Temperature dependence: $\rho - \rho_\circ = \rho_\circ\alpha(T - T_\circ)$

- **Power in an electrical device:** $P = iV$ Power dissipated in a resistor: $P = i^2R = \frac{V^2}{R}$

- **Definition of** *emf* : $\mathcal{E} = \frac{dW}{dq}$

- **Resistors in series:** $R_{eq} = \sum R_i$ Resistors in parallel: $\frac{1}{R_{eq}} = \sum\frac{1}{R_i}$

- **RC circuit:** Charging: $q(t) = C\mathcal{E}(1 - e^{-\frac{t}{\tau_C}})$, Time constant $\tau_C = RC$, Discharging: $q(t) = q_oe^{-\frac{t}{\tau_C}}$

- **Magnetic Fields:**

  Magnetic force on a charge q: $\vec{F} = q\vec{v}\times\vec{B}$ Lorentz force: $\vec{F} = q\vec{E} + q\vec{v}\times\vec{B}$

  Circular motion in a magnetic field: $r = \frac{mv}{qB}$ with period: $T = \frac{2\pi m}{qB}$

  Magnetic force on a straight length of wire: $\vec{F} = i\vec{L}\times\vec{B}$

  Magnetic Dipole: $\vec{\mu} = Ni\vec{A}$ Torque: $\vec{\tau} = \vec{\mu}\times\vec{B}$ Potential energy: $U = -\vec{\mu}\cdot\vec{B}$

- **Generating Magnetic Fields:** Biot-Savart Law: $d\vec{B} = \frac{\mu_0}{4\pi}\frac{id\vec{s}\times\vec{r}}{r^3}$

  Magnetic field of a long straight wire: $B = \frac{\mu_0}{4\pi}\frac{2i}{r}$ Magnetic field of a circular arc: $B = \frac{\mu_0}{4\pi}\frac{i}{r}\phi$

  Force between parallel current carrying wires: $F_{ab} = \frac{\mu_0 i_a i_b}{2\pi d}L$

  Ampere's law: $\oint\vec{B}\cdot d\vec{s} = \mu_0 i_{enc}$

  Magnetic field of a solenoid: $B = \mu_0 in$ Magnetic field of a dipole on axis, far away: $\vec{B} = \frac{\mu_0}{2\pi}\frac{\vec{\mu}}{z^3}$