Formula Sheet for LSU Physics 2113, Third Exam, Fall '16

- **Constants, definitions:**

$g = 9.8\,\frac{\text{m}}{\text{s}^2}$
$G = 6.67 \times 10^{-11}\,\text{m}^3/(\text{kg}\cdot\text{s}^2)$
$c = 3.00 \times 10^{8}\,\text{m/s}$
$e = 1.602 \times 10^{-19}\,\text{C}$
$1\,\text{eV} = e\,(1\text{V}) = 1.60 \times 10^{-19}\,\text{J}$
$m_p = 1.67 \times 10^{-27}\,\text{kg}$
$m_e = 9.11 \times 10^{-31}\,\text{kg}$
dipole moment: $\vec{p} = q\vec{d}$

$\varepsilon_o = 8.85 \times 10^{-12}\,\frac{\text{C}^2}{\text{Nm}^2}$
$R_{Earth} = 6.37 \times 10^{6}\,\text{m}$
$M_{Earth} = 5.98 \times 10^{24}\,\text{kg}$
$R_{Moon} = 1.74 \times 10^{6}\,\text{m}$
$M_{Moon} = 7.36 \times 10^{22}\,\text{kg}$
$M_{Sun} = 1.99 \times 10^{30}\,\text{kg}$
Earth-Sun distance $= 1.50 \times 10^{11}\,\text{m}$
Earth-Moon distance $= 3.82 \times 10^{8}\,\text{m}$
Circumference of a circle: $2\pi R$

$k = \frac{1}{4\pi\varepsilon_o} = 8.99 \times 10^{9}\,\frac{\text{Nm}^2}{\text{C}^2}$
Cylinder's side area: $A = 2\pi r \ell$
Volume of a cylinder: $V = \pi r^2 \ell$
Volume element: $dV = 2\pi \ell r dr$
Area of a circle: $A = \pi r^2$
Area element: $dA = 2\pi r dr$
Area of a sphere: $A = 4\pi r^2$
Volume of a sphere: $V = \frac{4}{3}\pi r^3$
Volume element: $dV = 4\pi r^2 dr$

Uniform charge densities: $\lambda = \frac{Q}{L}$, $\sigma = \frac{Q}{A}$, $\rho = \frac{Q}{V}$

- **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:**

$F_c = ma_c = \frac{mv^2}{r}$, $T = \frac{2\pi r}{v}$, $v = \omega r$

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

$K = \frac{1}{2}mv^2 \qquad \vec{F}_{\text{net}} = m\vec{a} \qquad E_{\text{mech}} = K + U$
$W = -\Delta U$ (by field) $\quad W_{ext} = \Delta U = -W$ (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): $a_g = \frac{GM}{r^2}$

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

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

- **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: $|\vec{E}| = k\frac{|q|}{r^2}$, An infinite line charge: $|\vec{E}| = \frac{2k\lambda}{r}$

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

At the center of uniformly charged arc of angle ϕ: $|\vec{E}| = \frac{\lambda \sin(\phi/2)}{2\pi\varepsilon_0 R}$

Along the line through the center of uniformly charged disk: $|\vec{E}| = \frac{\sigma}{2\varepsilon_0}\left(1 - \frac{z}{\sqrt{z^2 + R^2}}\right)$

Of an infinite non-conducting plane: $E = \frac{\sigma}{2\varepsilon_o}$

An infinite conducting plane or close to the conducting surface: $E = \frac{\sigma}{\varepsilon_o}$

Torque on a dipole in an $\vec{E}$ field: $\vec{\tau} = \vec{p} \times \vec{E}$, **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:** $\varepsilon_o \oint \vec{E}\cdot d\vec{A} = q_{enc}$

- **Electric potential, potential energy, and work:**
  $V_f - V_i = -\int_i^f \vec{E}\cdot d\vec{s}$ In a uniform field: $\Delta V = -\vec{E}\cdot\Delta\vec{s} = -Ed\cos\theta$
  $\vec{E} = -\vec{\nabla}V,\ \ E_x = -\frac{\partial V}{\partial x},\ \ E_y = -\frac{\partial V}{\partial y},\ \ E_z = -\frac{\partial V}{\partial z}$
  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: $\Delta U = q\Delta V = -W_{\text{field}},\ \ \Delta U = W_{ext}$ (if objects are initially and finally at rest)
  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: $U = \frac{q^2}{2C} = \frac{1}{2}qV = \frac{1}{2}CV^2$ 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. current density: $J = \frac{i}{A}$, 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: $\rho - \rho_\circ = \rho_\circ\alpha(T - T_\circ)$
- **Resistors in series:** $R_{eq} = \sum R_i$ Resistors in parallel: $\frac{1}{R_{eq}} = \sum\frac{1}{R_i}$
- **Power in an electrical device:** $P = iV$ Power dissipated in a resistor: $P = i^2R = \frac{V^2}{R}$
- **Definition of** *emf* : $\mathcal{E} = \frac{dW}{dq}$
- **Charging a capacitor, series RC circuit:** $q(t) = C\mathcal{E}(1 - e^{-\frac{t}{\tau_C}})$, 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: $\vec{F} = q\vec{E} + q\vec{v}\times\vec{B}$
  Radius for a Circular Motion in a magnetic field $\vec{B}$: $r = \frac{mv_\perp}{qB}$ with period: $T = \frac{2\pi m}{qB}$
  Magnetic force on a length of straight wire in a uniform $\vec{B}$: $\vec{F} = i\vec{L}\times\vec{B}$
  Magnetic Dipole: $\vec{\mu} = Ni\vec{A}$ Torque: $\vec{\tau} = \vec{\mu}\times\vec{B}$ Magnetic Potential Energy: $U = -\vec{\mu}\cdot\vec{B}$
- **Generating Magnetic Fields:** $(\mu_0 = 4\pi\times10^{-7}\frac{\mathrm{T\cdot m}}{\mathrm{A}})$ 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: $B = \frac{\mu_0}{2\pi}\frac{i}{r}$, Mag. field at the arc center: $B = \frac{\mu_0}{4\pi}\frac{i}{r_{arc}}\phi$
  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: $\vec{B} = \frac{\mu_0}{2\pi}\frac{\vec{\mu}}{z^3}$