Formula Sheet for LSU Physics 2113, Third Exam, Fall ’14

- **Constants, definitions:**
  - $g = 9.8 \text{ m/s}^2$
  - $G = 6.67 \times 10^{-11} \text{ m}^3\text{kg}^{-1}\text{s}^{-2}$
  - $M_{Sun} = 1.99 \times 10^{30} \text{ kg}$
  - $\varepsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$
  - $c = 3.00 \times 10^8 \text{ m/s}$
  - dipole moment: $\vec{p} = q\vec{d}$
  - Area of a circle: $A = \pi r^2$
  - Area of a cylinder: $A = 2\pi r\ell$
  - Area of a sphere: $A = 4\pi r^2$
  - Volume of a cylinder: $V = \pi r^2\ell$
  - Volume of a sphere: $V = \frac{4}{3}\pi r^3$

- **Units:**
  - Joule = $J = \text{N} \cdot \text{m}$

- **Kinematics (constant acceleration):**
  - $v = v_0 + at$
  - $x - x_0 = \frac{1}{2}(v_0 + v)t$
  - $x - x_0 = v_0t + \frac{1}{2}at^2$
  - $v^2 = v_0^2 + 2a(x - x_0)$

- **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):**
  - $K = \frac{1}{2}mv^2$
  - $\vec{F}_{\text{net}} = m\vec{a}$
  - $E_{\text{mech}} = K + U$
  - $W = -\Delta U$ (by field)
  - $W_{\text{ext}} = \Delta U = -W$ (if objects are initially and finally at rest)

- **Gravity:**
  - Newton’s law: $|\vec{F}| = \frac{Gm_1m_2}{r^2}$
  - Gravitational acceleration (planet of mass $M$): $a_g = \frac{GM}{r^2}$
  - Gravitational Field: $\vec{g} = -\frac{GM}{r^2}\hat{r} = -\frac{dV_g}{dr}$
  - Gravitational potential: $V_g = -\frac{GM}{r}$
  - Law of periods: $T^2 = (\frac{4\pi^2}{GM})r^3$
  - Potential Energy: $U = -\left(\frac{Gm_1m_2}{r_{12}} + \frac{Gm_1m_3}{r_{13}} + \frac{Gm_2m_3}{r_{23}} + \ldots\right)$
  - Gauss’ law for gravity: $\int_S \vec{g} \cdot d\vec{S} = -4\pi GM_{\text{ins}}$

- **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: $|\vec{E}| = \frac{2k\lambda}{z^3}$
  - Torque on a dipole in an electric 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: $\epsilon_o \oint \vec{E} \cdot d\vec{A} = q_{enc}$

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

- 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: $\Delta V = -\vec{E} \cdot \Delta \vec{s} = -Ed \cos \theta$
  - $\vec{E} = -\vec{\nabla}V, \ E_x = -\frac{\partial V}{\partial x}, \ E_y = -\frac{\partial V}{\partial y}, \ E_z = -\frac{\partial V}{\partial z}$
  - Potential of a point charge: $V = k\frac{q}{r}$  
    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: $\Delta U = q\Delta V$  
    $\Delta U = -W_{field}$
  - Potential energy of two point charges: $U_{12} = W_{ext} = q_2 V_1 = q_1 V_2 = k \frac{q_1 q_2}{r_{12}}$

- Capacitance: definition: $q = CV$
  - Capacitor with a dielectric: $C = \kappa C_{air}$
  - Parallel plate: $C = \epsilon_o \frac{A}{d}$
  - Potential Energy in Cap: $U = \frac{q^2}{2C} = \frac{1}{2} qV = \frac{1}{2} CV^2$
  - Energy density of electric field: $u = \frac{1}{2} \kappa\epsilon_o |\vec{E}|^2$
  - 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: $\rho - \rho_o = \rho_o \alpha (T - T_o)$

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

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

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

- Loop rule in DC circuits: the sum of changes in potential across any closed loop of a circuit must be zero.

- Junction rule in DC circuits: the sum of currents entering any junction must be equal to the sum of currents leaving that junction.

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

- Magnetic Fields:
  - Magnetic force on a charge $q$: $\vec{F} = q\vec{v} \times \vec{B}$
  - Lorentz force: $\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$
  - Hall voltage: $V = v_d B d = \frac{i}{nle} B$  
    $d =$ width $\perp$ to field and $i$, $l =$ thickness $\parallel$ to field and $\perp$ to $\vec{E}$
Circular motion in a magnetic field: \( qv_\perp B = \frac{mv_\perp^2}{r} \) with period: \( T = \frac{2\pi m}{qB} \)

Magnetic force on a 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: \( (\mu_0 = 4\pi \times 10^{-7} \text{T} \cdot \text{m} \cdot \text{A}^{-1}) \)

Biott-Savart Law: \( d\vec{B} = \frac{\mu_0 i d\vec{s} \times \vec{r}}{4\pi r^3} \)

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

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

Ampere’s law: \( \oint \vec{B} \cdot d\vec{s} = \mu_0 i_{\text{enc}} \) \( \) Magnetic field of a solenoid: \( B = \mu_0 i_n \)

Magnetic field of a toroid: \( B = \frac{\mu_0 iN}{2\pi r} \) Magnetic field of a dipole on axis, far away: \( \vec{B} = \frac{\mu_0 \vec{\mu}}{2\pi z^3} \)

- Induction:

Magnetic Flux: \( \Phi = \int \vec{B} \cdot d\vec{A} \)

Faraday’s law: \( \mathcal{E} = -\frac{d\Phi}{dt} \) \( (= -N\frac{d\Phi}{dt} \) for a coil with \( N \) turns) \( \) Motional emf: \( \mathcal{E} = BLv \)

Induced Electric Field: \( \oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi}{dt} \)

Definition of Self-Inductance: \( L = \frac{N\Phi}{i} \) \( \) Inductance of a solenoid: \( L = \mu_0 n^2 Al \)

EMF (Voltage) across an inductor: \( \mathcal{E} = -L\frac{di}{dt} \)

RL Circuit: Rise of current: \( i = \frac{\mathcal{E}}{R} (1 - e^{-\frac{t}{\tau_L}}) \) Time constant: \( \tau_L = \frac{L}{R} \) Decay of current: \( i = i_0 e^{-\frac{t}{\tau_L}} \)

Magnetic Energy: \( U_B = \frac{1}{2}Li^2 \) Magnetic energy density: \( u_B = \frac{B^2}{2\mu_0} \)