Summary on unit 1 (update: 9/11/10)

Constants: c=3×10^8m/s, $1u \approx m_p \approx m_n \approx 1.7 \times 10^{-27}$kg, $G = 6.7 \times 10^{-11} Nm^2/kg^2$.

Sec 1.1-1.9. Coord-vector: $\mathbf{r} =< x, y, z >= r\hat{\mathbf{r}}$, $r = \sqrt{x^2 + y^2 + z^2}$, $\hat{\mathbf{r}} =< cos\theta_x, cos\theta_y, cos\theta_z >$.
For 2D case, $r = \sqrt{x^2 + y^2}$, $\hat{\mathbf{r}} =< cos\theta, sin\theta >=< cos\theta_x, cos\theta_y >$.

Vectors (Sec. 1.5): Addition, substraction, magnitude of a vector, unit vector, $\cdots$.

Displacement: $\Delta\mathbf{r} = \mathbf{r}_f - \mathbf{r}_i$. (Average velocity) = (Total distance traveled)/(travel time), or

$\mathbf{v}_{avg} = \Delta\mathbf{r}/\Delta t = (\mathbf{v}_1\Delta t_1 + \mathbf{v}_2\Delta t_2 + \cdots)/(\Delta t_1 + \Delta t_2 + \cdots)$.

Position up date: $\mathbf{r}_f = \mathbf{r}_i + \mathbf{v}_{avg}\Delta t$.

Instantaneous velocity: $\mathbf{v} = Lim_{\Delta t \to 0}(\Delta\mathbf{r}/\Delta t)$. Instantaneous acceleration: $\mathbf{a} = d\mathbf{v}/dt$.

For constant acceleration , $\mathbf{v}_{avg} = \left(\frac{\mathbf{v}_f + \mathbf{v}_i}{2}\right)$. Otherwise, for sufficiently small Δt, use e.g. $\mathbf{v}_{avg} \sim \mathbf{v}_f$.

Momentum: $\mathbf{p} = \gamma m\mathbf{v}$, $\gamma = 1/\sqrt{1 - \beta^2}$, $\beta = |\mathbf{v}|/c$.

- Nonrelativistic approximation(NR): $\gamma \to 1$, $\mathbf{p} = m\mathbf{v}$.
- Identity: $\beta = \beta\gamma/\sqrt{1 + (\beta\gamma)^2}$, where $\beta\gamma = p/cm$. $\beta = v/c = (\Delta s/c)/\Delta t$. $\Delta s = \beta c\Delta t$.

The extended Newton's law of motion: $\mathbf{F} = \Delta\mathbf{p}/\Delta t$.

- If $\mathbf{F} = 0$, $\mathbf{p} = p\hat{\mathbf{p}} = constant$, which is Newton's first law.
- If $\mathbf{F} \neq 0$, for NR case, it leads to $\mathbf{F} = \Delta\mathbf{p}/\Delta t = m\mathbf{a}$, where $\mathbf{a} = \Delta\mathbf{v}/\Delta t$ is acceleration. This is Newton's second law. For the R case, $\mathbf{F} = \Delta\mathbf{p}/\Delta t = (\Delta\gamma/\Delta t)\, m\mathbf{v} + \gamma m\mathbf{a}$, with $\mathbf{a} = \Delta\mathbf{v}/\Delta t$.

Sec 2.1-2.8, also read 2.9.

Momentum principle: $\Delta\mathbf{p} = \mathbf{p}_f - \mathbf{p}_i = \mathbf{F}\Delta t$

Momentum Principle is given by a vector equation. The equation is valid for each Cartesian component.

A special case: 1d, NR and F=constant, or $a = F/m = constant$.

- From momentum principle: $\Delta\mathbf{p} = F_{net}\Delta t$. With $a = F/m$, it leads to $v_f = v_i + at$.
- For a constant acceleration case, $v_{avg} = (v_i + v_f)/2$. (Why?)
- Position update: $\Delta s = v_{avg}\Delta t = (v_i + v_f)/2\Delta t$. This leads to $\Delta s = v_i\Delta t + (1/2)a\Delta t^2$. (Derive)

Sec 3.1-3.5. Four kinds of forces(or interactions): Gravitational, electromangetic, strong and weak.

Gravitational force: $\mathbf{F} = -\frac{GMm}{r^2}\hat{\mathbf{r}}$. Near surface of earth (with radius R) $F = mg = m\left(\frac{GM}{(R+h)^2}\right) \approx m\left(\frac{GM}{R^2}\right)$.

Iterative procedure(3d):

- Begin with the object's momentum and position $(\mathbf{p}_i, \mathbf{r}_i)$, and the force $\mathbf{F}(\mathbf{r}_i)$ at $t = t_i$
- **IL**, Iterative Loop: Take time step $t_f = t_i + \Delta t$. Apply Momentum principle to update $\mathbf{p}_i$ to $\mathbf{p}_f$.
- Position update moves the object from $\mathbf{r}_i$ to $\mathbf{r}_f$.
- Set present $(\mathbf{p}_f, \mathbf{r}_f)$, $\mathbf{F}(\mathbf{r}_j)$, t_f to next step $(\mathbf{p}_i, \mathbf{r}_i)$, $\mathbf{F}(\mathbf{r}_i)$, t_i Go to **IL**.

Principle of reciprocity (Newton's third law): Force on 2 due to 1 and force on 1 due to 2 satisfies the relationship: $\mathbf{F}_{1\,on\,2} = -\mathbf{F}_{2\,on\,1}$.

Spring force(1d): Magnitude satisfies the relationship $|F| = k|s|$. With sign: $F = -ks$, $s = L - L_0$. The stretched case has $s > 0$, leading to attraction. The compressed case has $s < 0$, leading to repulsion.