- $\vec{r}(t)$, $\vec{v}(t) = \dot{\vec{r}}(t)$, $\vec{a}(t) = \dot{\vec{v}}(t)$
- $m\ddot{\vec{r}} = \vec{F}$, Newton
- General $\vec{F} = \vec{F}(\vec{r}, \vec{v}, t)$
- Fields $\vec{F}(\vec{r}, t)$
- $m\ddot{\vec{r}}(t) = \vec{F}[\vec{r}(t), t]$, vectorial,
  $\Rightarrow$ ODEs $\Rightarrow$ particle orbits
- circular motion, $a = v^2/r = r\omega^2$
- Inertial Frames
- $\vec{F}_{12} = -\vec{F}_{21}$, some cases $(A = R)$
- Lorenz Force $\vec{F} = \vec{v} \times \vec{B}$ $(A \neq R)$
- FBD's
- $\dot{\vec{P}} = \vec{F}_{ext}$; $\dot{\vec{P}} = 0$, only internal forces and $A = R$
- Constants of motion
- Conservation of $\vec{P}$, Rockets, collisions

- Center of mass, $(\Sigma m)\vec{R} \equiv \Sigma(m\vec{r})$
- $\vec{P} = (\Sigma m)\dot{\vec{R}}$
- Angular momentum, w.r.t. origin
  $$\vec{L} \equiv m\vec{r} \times \vec{v}$$
- $\dot{\vec{L}} = 0$ if $\vec{F} \parallel \vec{r}$ (central forces)
- $\dot{\vec{L}}_{total} = 0$ if interparticle $\vec{F}$ is central and $A = R$, $\vec{F}^{ext} = 0$
- $\dot{\vec{L}}_{total} = \Sigma \vec{r} \times \vec{F}^{ext}$, external torques
- $\vec{L}$ for Rigid Bodies $\Rightarrow$ MI, etc
- Work, $dW = \vec{F} \cdot d\vec{r}$
- WE Thm, $dW = dK$
- Conservative forces: $\vec{F} \ni C \int_A^B d\vec{r} \cdot \vec{F}$ is <u>independent</u> of C
- Line integrals; direct, parameterize, etc

- Properties of conservative Fields

$$\boxed{\oint_C \vec{F}\cdot d\vec{r} = 0}$$

$$\boxed{\vec{F} = -\vec{\nabla} U} \iff \boxed{\vec{\nabla}\times\vec{F} = 0}$$

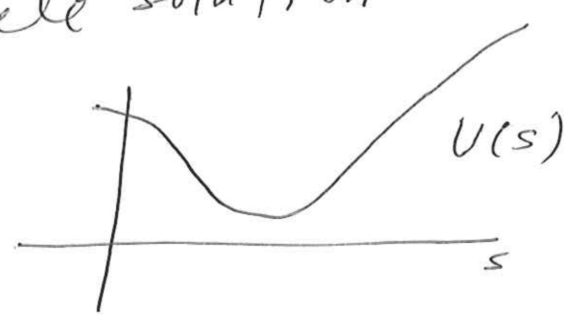
- Can find U from $\vec{F}$ if $\vec{\nabla}\times\vec{F} = 0$
- From WE Thm, if $\vec{F}$ is conservative

  $\Rightarrow \mathcal{E} = \frac{1}{2}mv^2 + U(\vec{r})$ is a constant

- Partial solution of Newton's equations using $\mathcal{E}$
- 1-D motion, $m\ddot{s} = F(s)$

  $\Rightarrow F(s) \equiv -dU/ds \Rightarrow \mathcal{E} = \text{constant}$

- Can use $\mathcal{E}$ in 1-D motion to obtain complete solution
- 1-D potentials



$\Rightarrow$ equilibrium point
$\Rightarrow$ stability
$\Rightarrow$ frequency of small oscillations

- Harmonic oscillator

$$m\ddot{x} = -kx$$

$\Rightarrow$ amplitude, phase, resonance

- Damped Harmonic oscillator

$$m\ddot{x} = -kx - b\dot{x}$$

$\Rightarrow$ damping rate, resonance height, resonance width

- approximations
- self-consistency