

★Reading: chapter 8.

- Momentum $\vec{p} = m\vec{v}$. Newton's 2nd law is better written as $\vec{F} = \frac{d}{dt}\vec{p}$. For constant mass this is the same as $\vec{F} = m\vec{a}$, but for non-constant mass (e.g. rockets, leaking containers, etc) the two expressions differ and the correct one always is

$$\vec{F} = \frac{d\vec{p}}{dt} \quad \text{always.}$$

- Integrating this we have

$$\Delta\vec{p} \equiv \vec{p}_f - \vec{p}_i = \int_{t_i}^{t_f} \vec{F} dt,$$

and Δp is called the impulse.

Act with force over distance and time: $\Delta K = \int \vec{F} \cdot d\vec{s}$, $\Delta\vec{p} = \int \vec{F} dt$.

The concept of impulse is not that deep or important, it's just the change in momentum.

- Something that is deep and important is conservation of momentum. Consider two objects A and B , interacting with each other but without external force. By Newton's 3rd, $\vec{F}_{A \rightarrow B} = -\vec{F}_{B \rightarrow A}$. This implies $\frac{d}{dt}\vec{p}_{total} = 0$. The total momentum of a closed system is always conserved! When the system is not closed, momentum can change, but that's only because it's being transferred from somewhere else. Fundamentally, accounting for everything, momentum is always conserved – just like energy!

- Example: astronaut push off in space, and \vec{p} conservation.

- Examples of impulse: ball bouncing on wall: $p_x = -12$, $p'_x = +8$, $\Delta t = 0.01$, get $F_{ave} = 2000N$.

- Quarterback sack example. Mike $m_M = 50kg$, $v_M = 8m/s$ vs Bubba with $m_B = 4m_M$ and $v_B = \frac{1}{4}v_M$. Equal momenta, require equal impulse to be stopped, but $K_M = 4K_B$, so 4 times the work and 4 times the distance in order to stop Mike.

- Rifle recoil example: bullet velocity and mass $v_B = 200$, $m_B = 0.005$, and rifle mass $m_R = 3kg$. The recoil velocity of the rifle is $v_R = -m_B v_B / m_R = -0.5$, and kinetic energy is $K_R = 0.375J$ and $K_B = 225J$. So work done by target to stop bullet is ≈ 600 times larger than that done by hunter to absorb the rifle's recoil.