# Activity 1: Newton's Laws

1. **Simple Example of Newton's 2$^{\text{nd}}$ law:** Consider a particle of mass $m$ being acted on by a constant force $\vec{F}_0$ pointing in the $\hat{x}$-direction:

$$\vec{F}_0 = F_0\hat{x}$$

   At time $t = 0$, the particle has velocity $v_0$ and position $x_0$. Find:

   (a) $\vec{a}(t)$

   (b) $\vec{v}(t)$

   (c) $x(t)$

2. **Newton's 3rd Law and Conservation of Momentum.** Newton's $3^{rd}$ law states:

> *If object 1 exerts a force $\vec{F}_{21}$ on object 2, then object 2 always exerts an* <u>*equal and opposite*</u> *reaction force $\vec{F}_{12}$ on object 1:*

$$\vec{F}_{12} = -\vec{F}_{21}$$

Consider a system of $N$ particles, each of which exerts a force on every other, see Fig. 1.

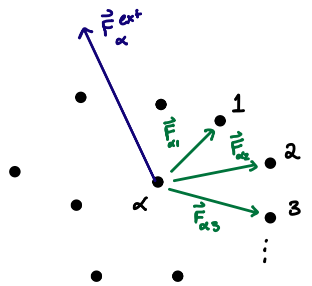


Figure 1: An $N$-particle system, which forces $\vec{F}_{ij}$ acting between all particles in the system (on particle $i$ by particle $j$), and an additional external force $\vec{F}^{\text{ext}}$ which acts on the $i^{\text{th}}$ particle with force $\vec{F}_i^{\text{ext}}$.

Consider one particle in the $N$-particle system, labelled "$\alpha$," identified near the center of Fig. 1. The total force acting on $\alpha$ is:

$$\vec{F}_\alpha^{\text{total}} = \vec{F}_\alpha^{\text{ext}} + \vec{F}_{\alpha 1} + \vec{F}_{\alpha_2} + ... + \vec{F}_{\alpha N}$$

(a) What is the instantaneous change of momentum of particle $\alpha$, or in other words, what is $\dot{\vec{p}}_\alpha$?

(b) Let $\vec{P}$ be the total momentum of the system:

$$\vec{P} = \sum_{\alpha=1}^{N} \vec{p}_\alpha$$

Consider $\dot{\vec{P}}$, the first time derivative of $\vec{P}$. Show that the following is true:

$$\dot{\vec{P}} = \vec{F}_{\text{total}}^{\text{ext}}$$

*Hint: Use Newton's third law.*

(c) If the net external force $\vec{F}_{\text{total}}^{\text{ext}} = 0$, what can we say about the total momentum $\vec{P}$ of the system?

3. **Newton's 2$^{\text{nd}}$ Law in Cartesian coordinates.** In Cartesian coordinates, we can write Newton's 2$^{\text{nd}}$ law,

$$\vec{F} = m\vec{a} = m\ddot{\vec{r}},$$

in component for as:

$$F_x = m\ddot{x}$$
$$F_y = m\ddot{y}$$
$$F_z = m\ddot{z}$$

Consider a golfer hitting a golf ball. The ball has an initial speed $v_0$ at an angle $\theta$ above the ground, see Fig. 2. The force of gravity points downward.

(a) Find $\vec{r}(t)$.

(b) Find the time of flight of the golfball. Assume the ground is completely flat.

(c) Find the range of the golfball.

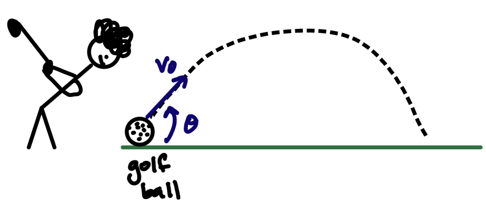


Figure 2