Example: A ball on a porch rolls 50 cm to the porch's edge, drops 45 cm, continues rolling on the grass, and eventually stops 90 cm from the porch's edge. What is the magnitude of the ball's net displacement? (Answer: 1.47 m)

$$\mathbf{\Delta r_{AB}} = \sum \mathbf{\Delta r} = \mathbf{\Delta r_{AB}} + \mathbf{\Delta r_{BC}} + \mathbf{\Delta r_{CD}}$$

$$\mathbf{\Delta r_{AB}} = \langle \Delta r_{ABx}, \Delta r_{ABy}, \Delta r_{ABz} \rangle = \langle 50, 0, 90 \rangle \text{ cm}$$

$$\mathbf{\Delta r_{AB}} = \langle 50, -15 \rangle \times 10^{-2} \text{ m}$$

$$|\mathbf{\Delta r_{AB}}| = \sqrt{\Delta r_{ABx}^2 + \Delta r_{ABy}^2} = 1.47 \text{ m}$$

**Careful!** $|\mathbf{\Delta r}| \neq \text{total distance traveled}$ (not necessarily)

**Ex.**

\[\mathbf{\Delta r_1} + \mathbf{\Delta r_2} \]

If $|\mathbf{\Delta r_1}| = |\mathbf{\Delta r_2}| = 10 \text{ m}$

then total $\Delta r_{\text{B1}} = (0 + 10 + 10) \text{ m}$

but $|\mathbf{\Delta r}| = 0$

**Average Velocity:** definition:

$$\mathbf{\bar{v}} = \frac{\mathbf{\Delta r}}{\Delta t} = \frac{\mathbf{r_f} - \mathbf{r_i}}{t_f - t_i} = \left( \frac{\Delta r_x}{\Delta t}, \frac{\Delta r_y}{\Delta t}, \frac{\Delta r_z}{\Delta t} \right)$$

**Ex.** Suppose $\mathbf{r_i} = \langle 3, 2 \rangle \text{ m}$, $\mathbf{r_f} = \langle 3, 4 \rangle \text{ m}$
Example: A person walks 12 m in a direction 40° east of north. They then walk 24 m in a direction 10° north of east. If this takes a total of two minutes, what was their average velocity overall? (Answer: <0.261, 0.111> m/s)