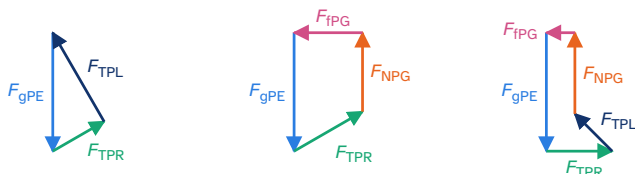


What a VAD shows

A force vector addition diagram (VAD) adds every force exerted on your system, **head to tail**, so you can see the result of all the forces together. It uses the same force arrows as your free body diagram (FBD), just rearranged. For now, the VAD is qualitative: compare lengths (longer, shorter, equal), with no numbers.



In each of these scenarios, the head of the last force lands on the tail of the first, so the result of all the forces exerted on the pumpkin is "nothing." The forces are balanced.

Start from a complete FBD

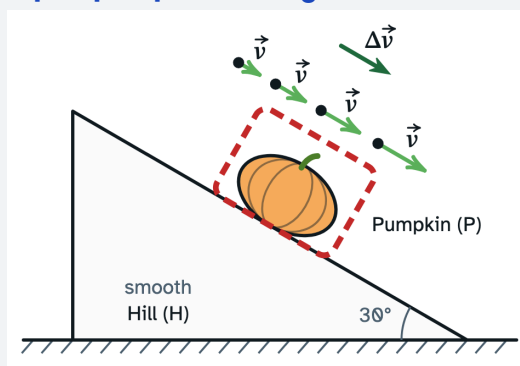
The VAD can only be as good as the FBD it comes from. Before you begin, check that your FBD has:

- **Your system**, identified with a system boundary in your ID and shown as a dot on your FBD.
- **One force for every interaction that crosses the boundary** in your interaction diagram (ID). No interaction, no force.
- **Type-On-By labels** on every force, for example F_{gPE} = gravitational force exerted ON the Pumpkin BY the Earth.
- **Correct directions**. You cannot change the direction of a force, so this is an important check.

Build the Force Vector Addition Diagram head to tail

1. **Copy the first force vector arrow.** Keep the same direction and relative length as in the FBD, and label it the same way. This is the first step of your "treasure map".
2. **Add the next force head to tail.** Put its tail on the head of the previous arrow. Never rotate a force arrow.
3. **Repeat until every force from the FBD is used once.** The order does not matter; any order gives the same result.
4. **Adjust lengths if you need to.** If you know two forces must be equal, or one must be larger, make the lengths match that reasoning. If you know the "treasure map" should end where it started, you should adjust the relative lengths accordingly. **DO NOT CHANGE THE DIRECTION OF ANY FORCE VECTOR.**

Example: pumpkin sliding down a smooth hill

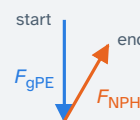


Free body diagram

Vector addition diagram



The normal force is perpendicular to the hill



Same directions, head to tail

1. **FBD:** the boundary around the pumpkin is crossed by two interactions, so there are two forces: F_{gPE} straight down and F_{NPH} perpendicular to the hill. The hill is smooth, so there is no friction force.
2. **VAD:** copy F_{gPE} first; its tail is the start. Put the tail of F_{NPH} on the head of F_{gPE} , keeping its direction exactly as in the FBD.
3. **Read it:** the head of F_{NPH} does not land on the tail of F_{gPE} , so the result of all the forces exerted on the pumpkin is NOT "nothing." That is consistent with the motion map: the pumpkin is speeding up, so $\Delta v \neq 0$.

Quick VAD self-check

- ☐ Every force from the FBD appears exactly once, with the same label ("Type On By" subscripts).
- ☐ No arrow was rotated or reversed when it was moved.
- ☐ Each tail sits on the previous head, with no gaps or overlaps along the chain.
- ☐ No extra forces or arrows were added. Do not make up forces and do not draw motion arrows on FBD nor VAD.
- ☐ Does your VAD look balanced or unbalanced?