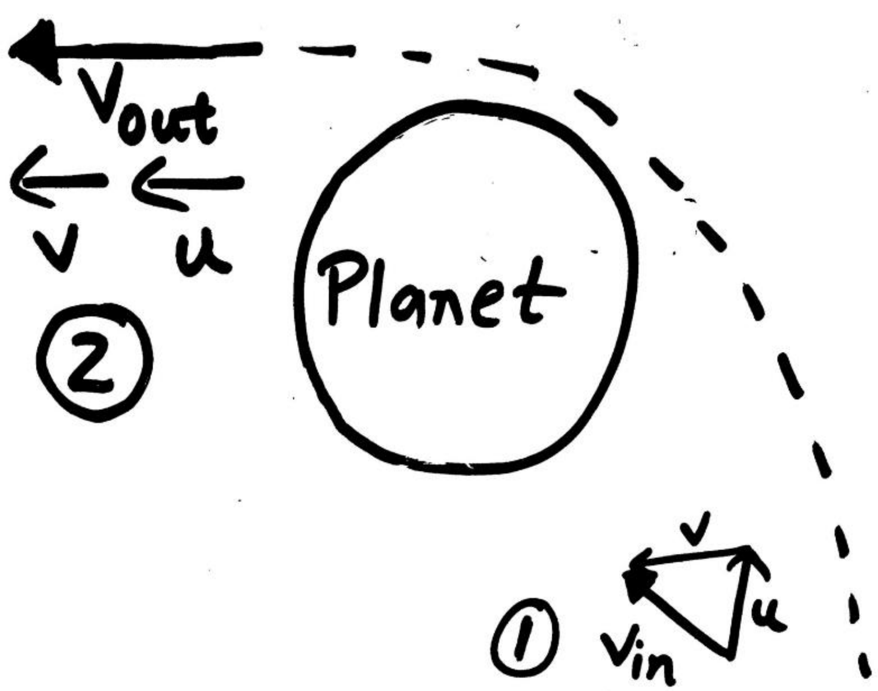
How the Voyagers Did It !

On launch, the Voyagers didn't have enough velocity to directly escape the Sun's gravity. It was and still is beyond our technological capability to do so. And so the Voyagers were made to slingshot around Jupiter and Saturn to gain extra velocity to be able to escape the Solar System. Its easy to understand how this works in terms of vectors. Unlike scalar quantities (like speed) which only have magnitude, vectors (like velocity) have both magnitude & direction. A change in direction implies change in velocity, which was quite useful to the Voyagers. Let's see how.

Consider a spacecraft approaching a planet with a trajectory as shown in the diagram below. Let the planet's velocity around the Sun be **`v`**. The spacecraft's velocity on approaching the planet is **`v(in)`** and when leaving the planet is **`v(out)`**, as shown in cases 1 and 2 respectively:



A spacecraft's trajectory (dashed lines) when approaching and leaving a planet. Beautifully self-drawn.

`v(in)` can be calculated by the Pythagorean Theorem (the square root of sum of squares of "horizontal velocity component" of the spacecraft **`v`** and "vertical velocity component" **`u`**). **`v(out)`** can be expressed as simply the sum of **`v`** and **`u`**, as you can infer from above. Here are the resulting velocity calculations for each case:

(1) $V_{in} = \sqrt{v^2 + u^2}$

Take $u = v$

$$V_{in} = \sqrt{v^2 + v^2} = \sqrt{2v^2}$$

$$V_{in} = 1{\cdot}4v$$

(2) $V_{out} = v + u$

Take $v = u$

$$V_{out} = v + V$$

$$V_{out} = 2V$$

Calculation of **v(in)** and **v(out)** assuming a scenario of **v=u**. **u** could have been any random number but for simplicity, it is taken to be equal to **v.**

From this simple calculation, we see that **`v(out)-v(in) = 2v-1.4v = 0.6v`** i.e the spacecraft gained 60% of the planet's velocity after the gravity assist, adding to its own. You can clearly see that a change in direction is causing an increase in velocity here. The spacecraft's velocity thus increases quite a bit and the goal is achieved using nothing but gravity.

The Voyagers did this twice, once with Jupiter and then with Saturn to achieve enough velocity so that they can escape our Sun's gravity. And reach for the stars.

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