

Flybys and Foci Scientific Appendix

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1 Appendix

Throughout the story I have done my best to keep the plot scientifically accurate and plausible. This section gives a more thorough explanation of some parts of the story that the reader may find interesting. The appendix is written assuming the reader has some basic knowledge of physics, to the level that can be found on Wikipedia.

1.1 Appendix A: Diving Towards the Sun

In Chapter 8, *Einstein* is put on a trajectory that passes close to the sun before performing its main burn to exit the solar system. This may seem unintuitive - the spacecraft first heads towards the sun to make it to a point very distant to the sun. *Einstein* is taking advantage of the Oberth Effect, where the most efficient place to perform an engine burn is deep in a gravity well.

The total energy of a body in orbit is the sum of the kinetic and potential energy:

$$E = \frac{1}{2}mv^2 - \frac{mMG}{r} = -\frac{mMG}{2a}$$

Where:

m = spacecraft mass

v = velocity

M = solar mass

G = universal gravitational constant

r = distance to the sun

a = semi-major axis

This expression is commonly divided by mass to get the *specific orbital energy*:

$$= \frac{1}{2}v^2 - \frac{MG}{r} = -\frac{MG}{2a}$$

For *Einstein* the higher the specific orbital energy the faster it will reach the sun's focal point. A more tangible measure is v_∞ , which is the spacecraft's velocity when it is so far away from the sun that its potential energy is negligible. As a spacecraft climbs out of the sun's gravity well it sheds velocity and the potential energy goes to 0 (in orbital mechanics potential energy is 0 at infinity and increasingly negative closer to the sun).

$$\begin{aligned} \frac{1}{2}v_\infty^2 &= \frac{1}{2}v^2 - \frac{MG}{r} = -\frac{MG}{2a} \\ v_\infty &= \sqrt{v^2 - \frac{MG}{r}} \end{aligned}$$

Where:

r = spacecraft distance to the sun

v = velocity at the given r

We can use this to calculate v_∞ for *Einstein* if it had burned directly on a hyperbolic escape trajectory and compare it to v_∞ from its trajectory that took it close to the sun.