Re: how much fuel my spaceship needs?

Source: http://sci.tech−archive.net/Archive/sci.physics.relativity/2007−07/msg02427.html

- *From*: The Ghost In The Machine <ewill@xxxxxxxxxxxxxxxxxxxxxx>
- *Date*: Sat, 21 Jul 2007 08:50:25 −0700

In sci.physics.relativity, virgil
<u7it34d@xxxxxxxxxxxx>
wrote
on Fri, 20 Jul 2007 15:31:05 −0700
<1184970665.951203.35720@xxxxxxxxxxxxxxxxxxxxxxxxxxxx>:

> i need to visit some friends of mine living on
> a planet 1 light year distance from earth
>
> tha engine of my space ship can maintain a
> constant 10g accl, burning fuel at a constant rate
>
> do i need to tank fuel for tha trip duration as seen
> from earth or for tha duration seen by me as traveler?
>
> how much fuel do i need to burn?

You forgot the exhaust velocity. The Newtonian form
of the Rocket Equation must have it:

v_f = v_i + v_e * log(M_i/M_f)

v_f = final velocity
v_i = initial velocity, usually 0
M_i = initial mass of propellant and payload
M_f = mass of payload only

There is a relativistic form but I'd have to find it, and
given the considerations below it is of limited usefulness.

The absolute best v_e I can deduce without antimatter
is something along the lines of a fusion
boron/hydrogen rocket, a hypothetical affair that
uses the reaction p + 11B5 −> 3 4He2 + 8.7 MeV.
Assuming that each alpha particle (rest mass 3727.38 MeV)
receives 2.9 MeV each (on average), that gives a
gamma of 1.0007780263885, and therefore a velocity of

v_e = sqrt(1−1/gamma^2) = 0.03942 c.

If one assumes a 20:1 fuel ratio, the most a single−stage spacecraft can achieve is therefore about 0.118 c. After that, one's out of fuel. At 0.118 c a spacecraft will see the trip as being only .993 lightyear, and it will take [*] roughly 8.41 years, but since rockets don't have brakes you might have to wave at your friend as you flash by −− or hit his planet rather hard. This is not good for the planet; at 0.118 c each kg of payload will hit with 634 teraJoules or 151 kilotons TNT. That's 10 times the yield of "Little Boy", and "Little Boy" weighed 4 metric tonnes.

And it is certainly not good for you, being at ground zero. ;−) If one assumes a Gemini−type capsule, one is looking at a 2735 kg affair, plus human would make that 2800 kg (give or take) and a yield of about 423 megatonnes. Since you said this was a friend I doubt it was your intention to declare nuclear war thereon... :−)

A more reasonable trip profile would travel at 0.059 c, most of it in free flight. The only thing that would hit the planet at near−relativistic velocity would be the alpha particles. At that speed one would see a shrinkage to 0.99825 lightyear, and a trip length of 16.905 years subjective. If one launches while pregnant (not the best of notions to begin with), this could lead to an interesting variant of "Are we *there* yet?" during flight...

Antimatter can be produced here on Earth (at very prodigious cost), but is hard to handle.

Note that fuel does not burn at a constant rate in a rocket, if one wants to have constant acceleration, as the rocket mass is constantly diminishing.

Contemporary chemical rockets have a v_e of about 2500 m/s = 8.333 * 10^−6 c.

As for the second part of your question, the amount of fuel you'll need would be related to the trip as seen in one's own reference frame, and not based on the trip as seen from the Earth (or from your friend's place). However, it's going to be a slow trip, and I hope your friend has some boron and water (or ammonia) to refuel with. :−)

[*] the calculations ignore the acceleration proper, which introduces an error of a few days −− which might wipe out most of the relativistic savings.

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#191, ewill3@xxxxxxxxxxxx
New Technology? Not There. No Thanks.

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