Interstellar flight 1

(by Thilo Gross)

I want to establish a base in another solar system and I need your help planning it. We will do this in 7 steps. First we need to figure out how long the trip to the destination will take, then we can think about what to bring and whom to take along.

Our target will be the closest star (well, second closest actually), Proxima Centauri. Proxima is only 4.243 light years away, which means light from the sun needs 4.243 years to get to Proxima.

But light is pretty fast, 300,000 km/s, so how far is Proxima actually away in m?

$$d =$$

Interstellar flight 2

(by Thilo Gross)

I want the spaceship to constantly accelerate for half the way, and constantly decelerate for the second half of the way.

The spaceship's engines can accelerate it at

$$a = 10\mathrm{m/s}^2$$

So if we accelerate for $t = 100\mathrm{s}$ what will be our velocity?

$$v(100\mathrm{s}) =$$

Can you write an equation for the velocity after accelerating for time t?

$$v(t) =$$

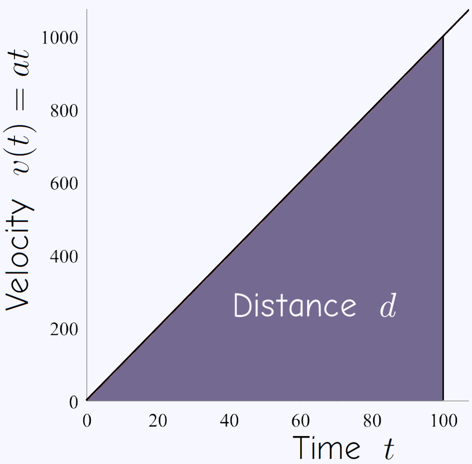
Interstellar flight 3

(by Thilo Gross)

After half the way we need to turn the ship around and fire our engines in the direction of Proxima to start decelerating. How long will it actually take to reach the halfway point? To work this out, we use the following trick:

Distance covered

If you plot your speed over time, the area under the curve is the distance covered up to a certain time. For constant acceleration this becomes a triangle, so we can use our knowledge of the area of triangles to find the distance covered.



Can you write an equation for d, the distance covered, as a function of acceleration a and time t?

$$d =$$

Interstellar flight 4

(by Thilo Gross)

Use the equation from the previous sheet to derive a formula for the time t it takes to go a distance, d, at a constant acceleration a

$$t =$$

How, long in years do we need to get to the half way point?

$$t_{\text{halfway}} =$$

So how long, in years, does the whole journey to Proxima take? (its shorter than you would think!)

$$t_{\text{Proxima}} =$$

Interstellar flight 5

(by Thilo Gross)

We could go on and compute the amount of fuel we need. But let's focus on something more important: food. Water and air can be recycled readily, but humans need to consume biomass to survive. Suppose we want to bring 1,000 people to Proxima, how much food do we need to bring for the journey and to survive the first year there? (Hint: You can start by thinking about how much food you eat per day)

An alternative to bringing food is growing biomass on board the ship. Adding vitamins as needed is relatively easy and because we will have to put up with nuclear power anyway, we can generate enough light to keep things growing.

The highest biomass production is achieved with algal growth tanks, which produce about 4g per day per litre of tank volume. Suppose that for our spaceship we can use tank units which weigh 300kg and each produce 1kg of dry biomass per day.

How long does a journey have to be so that the tank units are more efficient than just bringing the food? And, how many units do you want to install in our spaceship?

Interstellar flight 6

(by Thilo Gross)

We should also think about who we should bring. For instance our algal growth tanks need maintenance every 100 days and it takes a biosphere technician 6 hours to carry out the maintenance procedures on one tank. So how many biosphere technicians do we need?

What about physicians? Could one doctor look after all us?

If it is fun, go one, who else would you want to bring to keep the ship going and get a colony on a distant planet started?

Interstellar flight 7

(by Thilo Gross)

Congratulations you have made it through this set of exercises. Good work!

Of course if you enjoyed it you can always go on. There are plenty of questions related to the planned colony that benefit from mathematical considerations. For example how much energy do we need to produce to keep the spaceship going? How many people do we expect to die on the way to the destination? How many will be born? What else would we want to bring. Say, we want to build concrete domes as living space, how much concrete would be required? Or would it be more efficient to manufacture the concrete at the destination? In that case how long would it take till everybody would have a place to live on the surface of the planet?