STAR TRAVEL

<u>Basic problems</u>:

1. The speed of light "c" is an upper limit to speeds in the universe, and so we have no hope of traveling faster than light (as far as we know). And it is well-established that in order to approach a significant fraction (say 80%) of the speed of light requires stupendous amounts of energy, more than anyone has so far imagined from any kind of propulsion system. Even the amount of energy it takes to approach even a small fraction of the speed of light (say 0.1 c) is enormous.

The energy required to accelerate to a certain speed doesn't depend on what kind of fuel you use (see discussion on pp. 300-302), but it *does* demand that the *mass* of fuel you carry will have to be enormous—the mass needed does depend on the kind of fuel you use because different fuels have different mass-energy conversion efficiencies (see below).

2. There *are* designs that could in principle travel at 5-10% of the speed of light (as discussed in text and mentioned below; most of these are just out of reach of present technology). But stars are many light years apart, so even a one-way voyage to the nearest stars would require decades or centuries or more at a speed of 0.1 c. This will require a multigenerational crew, or suspended animation, or a very large increase in human lifespan to reach even the nearest stars. There are severe problems with each of these.

You may notice that the time problem could in principle be solved by robotic probes. (This assumes that those on Earth would be willing to wait the centuries required until the robots report home.) One interesting variant of these are called "von Neumann probes" –they are basically starships that make copies of themselves and launch the copies, which then replicate again and launch further copies, etc. A good tactic to colonize the Galaxy! This is not discussed until chapter 13 of your textbook.

(Note that both of these problems arise because of the large distances between stars—as if the Galaxy is constructed to prohibit interstellar travel. Think about distances within our Galaxy—how large is our Galaxy? What if the nearest planet with life is 1,000 ly away?)

Propulsion

Most propulsion systems rely on using some kind of fuel.

Can think about these in terms of $E = X mc^2$ where X is some fraction (<1). Different fuels have different efficiencies X.

Chemical fuels (like present-day rockets): X extremely small, no chance of getting to other stars in a reasonable amount of time, without carrying a ridiculously large supply of fuel.

Nuclear fission: we know how to control fission, and X is larger than for chemical fuels, but still rather small—amount of mass of fuel you'd need for a given payload mass (the "mass ratio") would be enormous. A more basic problem is that radioactive isotopes that undergo fission are rare, so it is difficult to see where you'd get enough fuel.

Nuclear fusion: we *don't* yet know how to control fusion, but it is in the foreseeable future. In this case we can get X of about a percent. That turns out to be enough to get a starship up to 0.1 c in a reasonable time. But the amount of fuel you need still seems prohibitive. But in this case, unlike for fission, the fuel will not be rare: you can use hydrogen, the most abundant element in the universe

Proposals: Project Orion, Project Daedalus, Bussard ramjet, … (see textbook; we will discuss ramjet in class).

Bussard Ramjet—pick up the fuel on the way, by sweeping up interstellar hydrogen to feed the nuclear reactor! In principle you could get arbitrarily close to the speed of light. But shielding is a problem (as you get to even a fraction of the speed of light, those interstellar atoms and dust grains impact with enormous energies), and worse yet, it requires enormous collector area, even to get to 0.1 c. Magnetic collectors have been proposed, but no one knows how to generate a magnetic field that large.

Matter-antimatter: This is most efficient fuel possible, with complete conversion of mass to energy (X =1). The problem is that we have no idea how to store matter and antimatter without them annihilating each other, or how we would make enough antimatter in the first place.

Our universe has the mysterious property that a slight asymmetry, which must have arisen when the universe was very young, resulted in a universe that had a slight excess (about one part in 100 million) of matter over antimatter. After the matter and antimatter annihilated each other, only this excess matter (the matter we see today) remained. That is why we would have to produce the antimatter ourselves, but that requires an enormous amount of energy (as you might expect!).

Other suggestions (see textbook for more detail):
<u>Ion engine</u>—accelerate charged particles (ions) in an electric or magnetic field. There are groups working on this very seriously, but it will only be able reach speeds at most 1% the speed of light (and that is optimistic).

<u>Solar sails</u>—nice idea, but the inverse square law of light means you have to accelerate very close to the sun and then coast the rest of the way. It might be possible to get to 0.02 c or so this way.
<u>Laser sails</u>—this would be much better because a laser (if powerful enough!) could provide a continuous "push" on the starship sail. There would be several interesting ways of reaching very high speeds with laser sails *if* laser beams could be built that were powerful enough (your book estimates 1000 times the current total human power consumption) and could focus the beam tightly enough (called "collimation").

Besides the problem of energetic lasers, there is also the problem of landing when you arrive at your destination…Think about it.

Further topics:

Read your book about the interesting effects that would occur if we (or someone) *could* travel near the speed of light. The effect of "time compression" is the most interesting, since it implies that a near-light-speed astronaut might hardly age even on a journey that appeared to take centuries to Earth observers. (This effect has been measured many times in experiments, so it is not science fiction at all. However we have no idea how to get so close to the speed of light.)

Please read the section of your book on Wormholes and Hyperspace (pp. 313-314). I will not include this on the exam.

Similarly, read sec. 12.6 "Are Aliens Already Here," but, as I explained in class, I will only ask you one, very general question about this material.

There are no notes on Chapter 13, The Fermi Paradox. We will discuss it very briefly in class, but for the most part you are expected to read all of that chapter, and there will be several questions about it.