Question 1:

Dear Cheap Astronomy – What will the first Moon base be anything like Artemis?

Andy Weir, author of The Martian, has since written ‘Artemis’ a tale about a lunar colony which has prompted people to start thinking about how the first Moon base might operate. For Artemis, the smelting of anorthite to extract is key to the colony’s success and to the novel’s plot. Anorthite smelting gives you metal for building and the oxygen to let you live in the buildings that you build. Although surprisingly, in Artemis ,people live in 100 per cent oxygen at 20 per cent of atmospheric pressure. In reality, long term exposure to 100 per cent oxygen is not good for you and it’s unlikely anyone could light a cigar in that environment (which happens in the book) without it exploding into flame. It’s also not clear where the water comes from. It’s made clear that water is a scarce commodity that’s carefully recycled, but that’s about all we’re told.

The aluminium smelting requires a huge amount of energy, which is drawn from nuclear generators. Apparently you just can’t manage it with solar panels. So, it’s perhaps optimistic to have set Artemis about 60 years in the future – which requires us to not only get back to the Moon, but also to build two working nuclear reactors on it. These are apparently fission reactors and hence are existing technology, but actually building them will be challenging.

Nonetheless, Mr Weir is spot on that if you want a lunar colony, you will need an energy source and going nuclear may well be the best option. There is nowhere on the Moon’s surface where you’ll get uninterrupted sunlight, even near the poles – unless perhaps you build a big tower on a hill. But with a nuclear reactor, you can set up your colony anywhere you want.

Anyhow, Andy Weir is right that you need an energy plan and you need an oxygen plan. Cheap Astronomy will also suggest that you’d probably want to dilute the oxygen to about 21% with an inert gas like nitrogen and pump up the air pressure to about 1 atmosphere. The nitrogen should be easy to manage, it’s light and compressible and, being chemically inert, none of it is really going to be consumed, so you just need to ship a certain volume to the Moon and then keep it there. Water is more problematic. It is recyclable, but humans are water sponges, so the more humans you have, the more water reserves you need to keep their inputs and outputs balanced. And that’s yet another argument for a polar base, since the poles may be where you’ll find the most water on the Moon – lying within permanently shadowed craters.

And as to what might drive us to build the first Moon base, Andy Weir really nailed it. It’ll be tourism. In Artemis the aluminium smelting isn’t done for the purpose of sending aluminium exports back to Earth – Earth has vast reserves as it is. The smelting is just to generate building material for the base and to get the oxygen. Indeed once the base is built, it’s pretty much just about the oxygen.

But, putting all the technology to one side, Artemis is a services-based economy, where people, that is staff, are there to support the various service industries that tourism depends on – the guided tours, the restaurants, the hotels and the gift shops.

Even if there was something worth mining for export from the Moon, you still wouldn’t really need a colony, you’d just do it with robots and telepresence – which is pretty much how it’s done in the Artemis story anyway. But if you want your skinny half-cap and a lox bagel with extra cream cheese, you're going to need a human service provider. And if you want human service providers, you're going to need a colony.

If we do want a lunar colony within sixty years, it's time to start making decisions about the energy plan, the oxygen plan and where the water's going to come from. The Artemis approach is bold and requires huge up-front investment. Given how humans tend to work, it's more likely we'll get there in little incremental steps. First, we need some robotic landings at the poles to confirm if there really is water in abundance there. If there is, you're good to go with solar panels, which can power the electrolysis of water into molecular hydrogen and oxygen. If there's not much water there, maybe we need to start planning for how we're going to divert some icy comets to crash on the far side. And that is what we really need, a plan.

Question 2:

Dear Cheap Astronomy – Why do we talk about microgravity in low Earth orbit?

The force of gravity on Earth's surface at sea level is 1G or since gravity is really an acceleratory force it's 9.8 metres per second per second. So, if you jump off a chair you'll accelerate at about 9.8 metres per second per second, as much as you will off a tall building. Unfortunately, jumping off a tall building will see you keep on accelerating, so by the time you do hit the ground, the speed will probably kill you.

But the more altitude you gain – that is, the further you are from the Earth's centre of mass, the weaker the force of gravity becomes. So, at the altitude of the International Space Station (about 400 kilometres above sea-level), the force of gravity is about 90%G – or about 8.8 metres per second per second – and at this altitude it is possible to fall around the planet. And since you maintain the same altitude all the way around, your speed doesn't increase.

Now, you might reasonably pause here and that think this is a bit odd. When you are in orbit, you are definitely falling and you are definitely in a gravity field, but for some reason you don't accelerate. You might speed up and down a bit in an elliptical orbit, but your nett speed should remain constant. From a Newtonian viewpoint you could explain this in terms of orbital mechanics. As you orbit, any increase in speed will raise the altitude of your orbit – which then shifts you into weaker gravity field which then reduces the acceleratory force that's acting on you. So, the nett balance of forces will work to keep you at a constant velocity and a constant altitude. The Einsteinian viewpoint of the situation is a bit different. If you are in a roughly circular orbit around a massive spherical body then you are always moving through a region of equivalent spacetime curvature. So, neither you, nor someone on the surface, should see your speed accelerate or decelerate.

So, if you are in orbit and you maintain a constant altitude you will maintain a constant nett velocity, even though you are in a gravity field which has a force of around 90% of what it would be on the Earth's surface. But then you might reasonably pause to wonder why in orbit you experience weightlessness. After all, if you are flying in a commercial jet at a constant velocity and altitude, you don't find yourself floating around the cabin. The answer to that is that the plane is resisting your natural tendency to fall – which means you can stand on the cabin's floor, because that floor is preventing you from following your natural tendency to fall towards the centre of the Earth.

So, on a plane, the plane is resisting your natural tendency to fall. But in an orbiting spacecraft, neither you nor the spacecraft are resisting that natural tendency to fall, both you and it are falling, but you are both moving so fast that you keep missing the ground and just keep falling around and around our spherical Earth.

So in orbit, you're falling, but since your falling without actually changing your altitude – that is, your distance from the Earth's centre of mass, you fall at a nett constant velocity – and unlike how it is in a plane, both you and your spacecraft are falling – so there's nothing that is going to hold you on to the floor of the spacecraft, you just float and as much as you might try to stand on a set of scales to measure your weight, you just keep on floating – and so must deduce that you are weightless –although, as you accelerate and decelerate very slightly in your passage through a slightly-elliptical orbit – will give you a sense that there is just a tiny bit of microgravity within your environment.

At the end of the day this is really about relativity. While you're in orbit, someone on the Earth's surface might think you are under the influence of 90% of Earth surface gravity and they'd be right. But for you – well, you are where you are, floating weightless in microgravity. There is no absolute correct explanation for what's happening. Nonetheless, everyone is correctly perceiving what's happening, relative to their frame of reference.