Question 1:

Dear Cheap Astronomy – Is anything truly transparent?

Well, yes a vacuum is truly transparent. Anything else, well, not really…

In a previous CA episode we've described how some materials absorb photons, while other materials allow those same photons to pass through them. The underlying principle is quantum mechanics. While an electron can absorb a photon and be raised to a higher energy shell, it will only absorb a photon that has the exact quanta of energy required to do that raising. So, even within the narrow wavelength range of optical light, some materials absorb photons and others don't.

But remember that the wavelength of light is an expression of its energy level and remember that light occurs across a huge spectrum of different wavelengths. So, some materials might be transparent to optical light, but be opaque to radio light – or vice versa – because radio light has different energy levels to optical light.

However, even transparent materials that don't absorb optical light can become opaque eventually. Several hundred metres down, the ocean (which, as you may be aware, is made of water) becomes totally dark. This is not because normally-transparent water does eventually start absorbing optical light photons, but because it scatters them.

So, to recap… water does absorb low energy long wavelength light – which is why microwaves can heat your coffee. Infra-red light is also mostly absorbed by water. Optical light is not absorbed, but longer wavelength red light photons are the first to be scattered as light penetrates the water and interacts with particulate matter or with water molecules themselves. Those interactions don't involve photon absorption, but they do begin to divert the straight line paths of photons that are passing through the water.

This is why scuba divers commonly report that, at depth, colours lose begin to lose their 'warmth' as red light is lost from their visual range. As you go deeper into the ocean more and more photons from shorter wavelengths also get diverted laterally, including eventually the blue and the violet ones, until there are no optical light photons left, still heading straight down – and so, consequently, it gets optically dark.

Looking down at the ocean from above the surface, deep water looks dark blue because no light is reflected back from the bottom, since of course most of that light never makes it to the bottom. Conversely, shallow water appears a lighter blue, or even green, as light can make it through to the sandy bottom and that light can also make it back out to your eye.

But, to get back to the point of the story, what we think of as transparency in materials is only true over certain distances. For example, glass is highly transparent, but a kilometre-thick piece of glass will probably be completely opaque – not due to absorption, but due to scattering.

The structural geometry of materials is also an issue. Although water is transparent to optical light, snow and ice certainly aren't – unless we're talking about very thin slices of ice. At the microscopic level, water freezes into a kind of crystalline matrix – which is less dense than fluid water, which is of course why ice floats on water.

When light interacts with frozen water, all the prismatic facets of these frozen ice particles cause extensive photon scattering across many different wavelengths, so that all the separate colours of optical light are first split, then scattered and then remixed. So when they are reflected back at your eye, they're all mixed up in the form of a pure white, which is why snow and also icebergs look white.

Mind you, glacial ice that's been compressed down to a denser, more uniform matrix produces less prismatic diffraction and reflection and so is more likely to behave like fluid water does – which is why dense glacial ice ends up having a blue colour. Cool, huh?

Question 2:

Dear Cheap Astronomy – How come some places on Earth have only one high tide a day, when others have two.

Tides on Earth are primarily caused by the Moon, although the Sun also plays an important role. As the Moon orbits the Earth it draws water from the seas and oceans towards it, creating a tidal bulge. And since the Earth and the Moon are actually both orbiting a common centre of mass called the barycentre, there is an almost-as-big tidal bulge on the opposite side of the Earth from the Moon, thrown outwards by the centrifugal force resulting from the Earth and Moon's joint orbit around their barycentre.

Since the Moon takes 27 days to orbit the Earth and the Earth takes only one day to rotate around its own axis, the Earth is always spinning quickly beneath those two slowly migrating tidal bulges – so any coastal areas on the Earth's surface that are spun beneath both the tidal bulges will get two high tides in the one day.

The height of those tides is somewhat dependent on the Sun – or at least on the relative positions of the Sun and the Moon. A Full Moon happens when the Moon is on the other side of the Earth from where the Sun is – meaning that on the Earth we see the Moon's nearside completely lit up. A New Moon happens when the Moon is on the same side of the Sun. In that configuration, the Moon's far side is lit up and to us its nearside is dark.

In either configuration, New Moon or Full Moon, the Earth, Moon and Sun are all lined up and the combined gravities of the Sun and Moon create spring tides – that is, the highest high tides – which occur about once every two weeks around a new or full Moon. And you also get neap tides, which are the lowest high tides when the Moon is at First Quarter or at Third Quarter – in other words, when the Moon is at either of the two points that are perpendicular to a line drawn between the Earth and the Sun.

So, broadly that's how tides work. However, there are other factors at play. Firstly, the Moon does not orbit the Earth's equator, which is quite unlike most other moons that we know about. We think that over billions of years, our Moon's orbital plane has slowly been dragged off the equator and into line with the ecliptic – that is, the orbital plane of all the planets around the Sun. This is consistent with the Earth being the closest planet to the Sun that has been able to hang on to a moon at all – remembering that neither Mercury nor Venus have any moons.

Secondly, the Earth spins on an axis that is tilted 23.5 degrees to the Solar System's orbital plane. So, the end-result of the Moon's unusual orbit and the Earth's axial tilt is that the Moon's orbit crosses over both the Earth's northern and southern hemispheres during one orbit and those orbits precess steadily around the Earth in a pattern that repeats every 8.9 years.

So, most places on Earth do experience two high tides a day as the Earth's orbit shifts those places through one Moon-induced tidal bulge and then the other. But, due to the differential orbital planes, the axial tilt and the precessions we've talked about, those same places will sometimes experience just one high tide a day as the Earth's orbit shifts them through one Moon-induced tidal bulge and then misses the other – or at least partially misses the other. This happens in a seemingly-haphazard, though entirely-predictable, pattern.

But all that said, the shape and depth of coastal geography is also a factor. Under perfect conditions, the highest theoretical change in tidal amplitude would be 93 centimetres, where those perfect conditions are a New Moon, when that Moon is in orbital periapsis with the Earth and the Earth is in orbital periapsis with the Sun. Such an ideal alignment of all these parameters is rare, but certainly possible.

However, a rise and fall of 93 centimetres is what you get in the open ocean. What you may get at your favourite fishing spot depends on coastal geography. In places like the Bay of Fundy in Canada, there is a maximum tidal amplitude change of more than 16 metres, as a large volume of sea water is gravitationally-shifted in and out of a relatively narrow channel.

So, the frequency of tides, as well as their height and their timing, varies widely across different parts of the world and over different days, months and years – but as long as you are willing to dig into the complexity a bit, it is all quite explainable and totally predictable.