Question 1:

Dear Cheap Astronomy – Can you fly though Saturn's rings without hitting anything?

At their thickest, Saturn's rings are about 1 kilometre thick. The region of greatest thickness is also the region of greatest density, being what are known as the A and B rings, which are about all you can see of Saturn's rings through a backyard telescope. The B ring is the wider inner ring, the A ring is the thinner and further-out one. The space between them is what is known as the Cassini Division. Subsequent rings, the C, D and E rings were found later as we invented more powerful telescopes. The F and the G rings were discovered by the Pioneer and the Voyager missions respectively. Going outwards from Saturn, the order of the currently-known rings are D, C, B, A, F, G and E.

Anyway, the question of whether you can fly through Saturn's rings without hitting anything is best considered by asking whether you could fly through the A and B rings – because if you can fly through those, then you can certainly fly through all the others.

We next need to deal with the meaning of the phrase 'without hitting anything'. You can fly through empty space and still hit a whole bunch of hydrogen atoms along the way. So perhaps we should be asking, can you fly through Saturn's A or B rings without hitting anything bigger than a breadbox? A breadbox, by the way, is a box that people in olden-times used to put bread in – seriously. And how big is a bread box? Well, it's about point five metres by point five metres by point five metres, give or take a few slices of bread.

So, can you fly through Saturn's A and B rings without hitting anything bigger than a bread box? Ah, were it so easy... The next issue we have to deal with is how big is your spacecraft? If it's a kilometre diameter sphere, then yes, you are most definitely going to hit something bigger than a bread-box when you fly through Saturn's A and B rings. But if your spacecraft was a Star-trek style shuttle craft, which is about the size of shipping container – then you probably could manoeuvre through Saturn's A and B rings on impulse power.

But if manoeuvring is cheating and you think we should adhere to a straight-line trajectory that is perpendicular to the plane of the rings, then it becomes a matter of probabilities. If you could wait for the right moment, scanning the rings for a line of sight gap then yes, it's possible you might get through. But if you have to close your eyes and just go for it – in your shipping-container-sized spacecraft straight through the A and B rings – then you will, probably, hit something hard that is bigger than a breadbox.

I hope that answers your question. Of course we did fly the Cassini spacecraft through Saturn's rings in 2004, although that was between the tenuous F and G rings at about 150,000 kilometres out from Saturn. It was necessary to bring the spacecraft that close to the planet in to enable orbital insertion. The combination of Saturn's gravity and a rocket burn slowed the spacecraft down to less than Saturn's escape velocity – although since then, Cassini has maintained an orbit that is more like 1 million kilometres out from Saturn and has never needed to fly though the rings again for over 8 years now. Come 2017 that will change, when Cassini approaches the end of its operating life and must be de-orbited to crash into the planet. Otherwise, there is a risk it might crash onto Enceladus or Titan and contaminate those potentially life-bearing worlds. So there may be more Cassini ring plane crossings ahead – stay tuned.

Question 2:

Dear Cheap Astronomy – Does 0.999 repeater equal one?

What we are actually dealing with here is Zeno's paradox. Zeno proposed a thought experiment – a race between a tortoise and a fast runner, with the fast runner's role being played by the ancient Greek hero Achilles.

The tortoise is given a head start of ten metres, which is about thirty feet for all you US and UK listeners. Achilles would quickly catch up that ten metre distance, but over that period of time the tortoise might have moved a further twenty centimetres. Achilles would then quickly catch up that additional twenty centimetres. But in that time the tortoise might have moved another millimetre, which would then require Achilles to make up that millimetre while the tortoise crossed a few more nanometres – and so on and so forth. Following this train of logic suggests that Achilles could never hope to overtake the tortoise.

A solution to the Achilles and the Tortoise conundrum is that 0.9999 repeating equals one. Some mathematicians will happily die on their swords rather than conceding this point, but it really is true. 0.9999 repeating really does equal one. Sure, there are an infinite number of sub-divisions between zero and one – but if something is progressing from zero to one, with sufficient momentum to get to one, then it will get to one. Nature proves this true every day.

You can prove it with maths too. Imagine x = 0.999 repeating. Now multiply both sides of the equation by ten. Then you get ten x equals 9.999 repeating. Now subtract x from both sides, remembering that x equals 0.999 repeating. So… you get 9x equals 9… and therefore x must equal one. Hooray!

Nonetheless, you can see an astronomical example of Zeno's paradox seeming to hold true when you watch, from a safe distance, while someone, and let's say it's Achilles, falls into a black hole.

As Achilles falls, he is accelerated by the intense gravity of the black hole. Indeed, that acceleration will be so extreme that Achilles will begin to approach the speed of light.

But while Achilles falls, he also enters a highly-contorted spacetime environment where, from the perspective of a distant observer, clocks run progressively slower and slower. So although Achilles should be accelerating, from your perspective he will appear to start slowing down as he approaches the point where clocks stop altogether – that point being the event horizon of the black hole.

So as Achilles falls towards the event horizon, it is as though he has to move through a growing number of subdivisions as he approaches, but never quite reaches, that point where time equals zero.

Of course, from poor Achilles' perspective, he fell and he died long ago. But the reflected light that informs you of the progress of his fall has to move from places where clocks run relatively slower. So, from your perspective, you get progressively slower updates about the progress of Achilles' fall and assume that he is actually slowing down. Indeed you will probably keep assuming that until eventually, the light that informs you of Achilles' progress becomes so red-shifted that he disappears from sight altogether, still almost but not quite reaching the event horizon finish line.