Question 1:

Dear Cheap Astronomy – since mass attracts mass due to space-time curvature, do charged particles attract each other in a similar way?

According to Einstein, gravity is the result of curved space-time. You don't accelerate in a gravity field because some mysterious force is dragging you downwards. You accelerate because clocks progressively slow and lengths progressively contract as you move closer to a massive object. In theory, the four forces, the strong, the weak, electromagnetism and gravity, all involve attraction across a distance, and all are mediated by particles, some observable, like the gluon, and some that are hypothetical, like the graviton.

In theory, the four forces can also be thought of as fields. For example, a gravity field or a magnetic field. Although an electromagnetic field is the more technically correct term. James Clerk Maxwell demonstrated mathematically and also experimentally that electric and magnetic fields should be considered 2 manifestations of the same thing. that is, an electromagnetic field. In his later career, Einstein had high hopes of achieving a similar outcome for the electromagnetic and gravitational fields, which he thought might represent 2 manifestations of some higher order physics. But the person who had successfully unified space and time into space-time had no such luck with gravity and electromagnetism.

But anyway, what is electromagnetism? How does it work? And does it work at all like gravity does? The physics of magnetic attraction is easy to observe, but difficult to explain. Magnetizable metals, like iron, nickel and cobalt, have the spins of their outermost paired valence electrons aligned. This configuration explains why these metals are attracted to magnets, as well as being magnetizable themselves. Most other things in the universe that have an electromagnetic field first had their elements ionized and then had all the freed electrons spun around in a coordinated way. Think of the Sun, Jupiter, or even just a small, coiled electromagnet here on Earth.

However, while spinning electrons are the source of electromagnetism, mediating the electromagnetic force is the job of a boson. And the boson involved in the electromagnetic force is, of course, the photon. After all, light is electromagnetic radiation. So, when a charge attracts an opposite charge, or when it repels a like charge. This is shown in a Feynman diagram as an exchange of virtual photons. Such Feynman diagrams are a useful way of describing and predicting electromagnetic interactions, and real photons have been shown to transfer spin, at least in the quantum mechanical sense of the word spin. Nonetheless, an exchange of virtual photons that conveniently appear when required and then disappear again sounds more like a mathematical model than genuine reality.

But seeking a deeper meaning from field interactions doesn't help much either. A charged particle can bend the electromagnetic field in a similar way to how mass bends space-time, and that bending of the electromagnetic field can alter the trajectory of another charged particle. But this doesn't easily explain why opposite charges attract and like charges repel. Quantum field theory has an answer, even though it's not a very satisfying answer. Masses are universally attractive because gravitons have spin too. while charges differentially attract or repel because their electromagnetic force carriers, photons, have spin one. If that helps you, well, great.

So, at the end of the day, it is quite difficult to explain why electromagnetism works, even though it clearly does work. For this reason, it's difficult to say whether there is any common mechanism underlying the operation of electromagnetism and gravity. For the moment, the best way to explain electromagnetism is with quantum physics and virtual photons. At the same time, it's relatively easy explaining how gravity works without ever needing to worry about hypothetical gravitons. I think we'll just leave it there.

Question 2:

Dear Cheap Astronomy – How realistic was Project Orion?

The idea of a spacecraft propelled by dropping nuclear bombs out the back was proposed back in the mid-1940s, floated again by researchers at Los Alamos in 1955 and then funded as a development project, that is Project Orion, from 1958 until 1964, when it was canned after the US government signed up to a global treaty banning nuclear explosions in space.

Currently our spacecraft either have high thrust, like the Saturn 5 which burns 3 million metric tons of fuel to achieve orbit or our spacecraft have high propellant efficiency, also known as specific impulse, such as an ion drive spacecraft can fly between planets on half a metric ton of propellant, although they do that very slowly.

A nuclear pulse drive has both high thrust and high propellant efficiency, since you expend a relatively small amount of mass, in the form of a nuclear pulse unit, what most of us would call a bomb, and gain a huge amount of thrust from its subsequent explosion.

The spacecraft was envisioned to be rocket-shaped and at its base was a pusher plate – essentially a large flat disk intended to take the full force of the bomb blast, gaining momentum from it as well as protecting the rest of the spacecraft from it. Between the pusher plate and spacecraft were shock absorbers, so that rather feeling hard jolts, the crew would experience a fairly linear acceleration arising from the cumulative effect of a series of blasts.

The force generated by a nuclear explosion in the vacuum of space is all about debris velocity – it’s only in an atmosphere that you’ll get a shock wave from the explosion. So, a lot of thought went into the design of the nuclear pulse units. These were cylindrical, with internal geometries, including radiation mirrors that directed most of the explosive blast in one direction – that is, back towards the spacecraft.

At the blast end of the cylindrical pulse units was a thick layer of tungsten, which was the actual propellant. When the bomb explodes out that end, the tungsten would disintegrate into fine particles, but those particles would be driven at huge velocities back towards the pusher plate.

Tungsten was presumably chosen as it has the highest melting and boiling point of any element and so would be most likely to remain in solid particulate form in the face of a nuclear explosion.

The Orion planners enthusiastically promoted the idea that you could build a nuclear pulse propulsion spacecraft with the technologies and materials available in the 50s and 60s. After all they did have nuclear bombs and building the rest of the spacecraft just required conventional materials. A prototype design envisioned a moderate-sized spacecraft driven by pulse units the size of soft drink cans and allegedly the designers consulted with the Coca Cola company about adapting the internal mechanism of soft drink vending machines which could move and sequentially release a series of soft drink can sized objects.

Questions remain about whether the pusher plate could remain intact in the face of repeated atomic blasts and there would no opportunity to replace it over a long distance space mission to a remote destination, but ultimately the design concept just isn't politically palatable since it requires building large numbers of small nuclear devices – where a deep space mission might need thousands of them and losing track of just one from a manufacturing plant on Earth might lead to a major terrorist incident. As with many great engineering ideas, people are the problem.