

# Transformers

## Introduction

The concept of *The Transformers* was created in 1983 by toy manufacturer Hasbro. Originally conceived as an animated series of twenty minute cartoons, the project was designed to assign personality and narrative to an imported series of plastic toys which could be manipulated from robot form to an alternative (alt) mode, usually a vehicle. Given this role, and the young target audience, Hasbro and its licensees have rebooted the concept every few years since it was first created, often retaining a subset of characters, but varying the back story and details, and introducing new characters and capabilities as required to promote the toy line. Several cartoon series, toy character cards, an animated movie, novels, children's books, audio productions and comic book series have all served to revitalize and expand upon the original concept.

The largest scale reboot has been the series of live action movies, which started in 2007 with *Transformers*, directed by Michael Bay, and continued with sequels *Revenge of the Fallen* and *Dark of the Moon*. Due to the requirement that the robot characters integrate seamlessly with human actors, this version was more in line with real world physics than some of the animated versions. Which, of course, is not to say that it is entirely correct!

In common with other versions, the movie universe of *Transformers* focuses on a group of sentient mechanical beings, divided into two factions (Autobots and Decepticons) fighting a long-running civil war. The robot frames of these 'Cybertronians' are animated by a source of energy known as a 'spark', and can be reshaped at will to imitate any vehicle or equipment of appropriate size.

Physics topics that can be explored in this context include:

- Mass, volume and subspace
- Gravity in *Dark of the Moon*.

## Mass, Volume and Subspace

*"Hold up, Headstrong! It's not the real thing! Look at how big he is!"*

*"FOOL! Galvatron can be any size he wants!"*

*- Rodimus Prime and Galvatron*

One problem encountered by the program creators when trying to integrate disparate toy models into a single narrative was one of scale. Several leading Decepticons and some Autobots transform into human-scale hand-held devices (<1 m in length). Others transform into jet aircraft (15 m), while the majority of Autobots transform into road vehicles (5-20 m). While there is some indication that size of the characters' robot form scales roughly with the alt-mode, this is by no means universally true and in some cases is clearly not the case. There are also examples of cases where characters can carry others of a similar size inside themselves at will. The Transformers must have a method of changing their volume and also, given that some can be carried by human beings, their mass.

The animated versions of the series have an explanation for this - originally proposed by fans, and adopted by official sources - the use of subspace. Subspace is described as a kind of pocket dimension which can be used to store objects, or to store mass temporarily. It's fair to say our current standard model of the Universe does not accommodate this kind of mass displacement. However, it's worth noting that there are ideas such as String Theory or Super-symmetry that do suggest something rather similar. The mathematics of string theory require the existence of additional dimensions beyond the

four (length, breadth, height and time) we can perceive. These are present at all points in space-time simultaneously, and yet are so tightly coiled that they cannot be accessed. If Cybertronians can indeed access these, then they may explain the ability of transformers to produce weapons from nowhere, and to shift their mass as required. Even so, we should bear in mind energetic considerations - transferring mass outside of the four dimensions of space-time would release an energy equivalent to  $mc^2$ , where  $m$  is the mass in question and  $c$  is the speed of light, while restoring it would require the same in reverse. Hence it must be assumed that the 'spark' which animated Cybertronians has an impressive capacitance, and can transform energy between states with negligible losses.

It's worth noting that the creators of the 2007 movie and its sequels have stated that they designed the Cybertronian characters in the film to plausibly transform without changing mass or volume - and hence to negate the need for subspace. While this is true in some cases, the film nonetheless runs into similar problems of scale (notably the relative sizes of jet-formers and automobile-formers, and the ability of the AllSpark to reduce its volume). Nonetheless, assuming that the majority of transformations in the live-action film continuity do *not* involve subspace or similar technology, there remains a problem of mass. The supporting literature describes Optimus Prime as weighing some 4.3 tonnes - the appropriate mass for his truck trailer alt-form. However in robot-mode, the characters are capable of causing minor earthquakes while they walk, and shattering concrete underfoot. A 4300 kg robot, walking on two feet each with a surface area of about 2 m<sup>2</sup>, will exert a pressure of 10750 Pa, or 1.6 pounds per square inch - nowhere near enough to crack concrete, which typically has a strength measured in thousands of pounds per square inch. It is rather clear that in robot form, Optimus Prime is rather more massive than his vehicle mode - as indeed are many of the others!

## When Worlds Collide

*"You're very smart. You see, they can't rebuild without a slave labour force. How many rocks out there offer six billion workers?"*

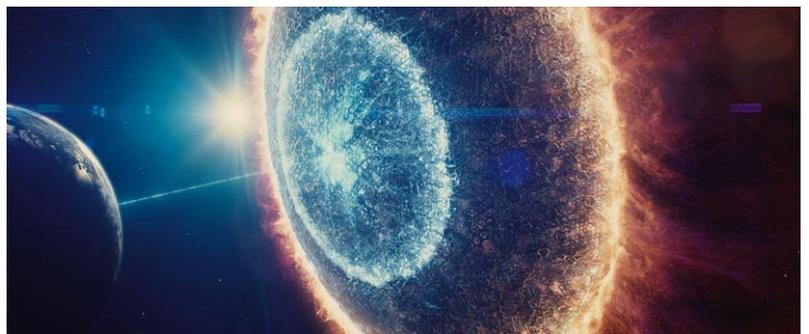
*"What are you talking about? We can't ship six billion people..."*

*"They're not shipping people. They're shipping their planet here!"*

*- Dylan and Carly, Dark of the Moon*

A recurring story-line in several *Transformers* versions involves the transportation of the planet Cybertron into close proximity with Earth. This was visualized on the big screen in the 2011 film *Dark of the Moon*, although in the film version, the plan was foiled, Cybertron never arrived and the 'space bridge' collapsed. Setting aside the difficulties of transporting a planet, let's consider the possible consequences of 'success'.

Cybertron is conventionally represented as a very massive planet, several times larger than Earth in diameter and about the same size as Saturn. While it is not a solid body, with the outer layers being made up of superposed layers of ancient structures to considerable depth, and it is made entirely of a metal, cybertronium, that closely resembles steel.



*The planet Cybertron, partly materialized in the near vicinity of Earth, from 'Transformers: Dark of the Moon' (2011).*

Given it's semi-hollow nature, we can take an optimistic order-of-magnitude estimate and suggest it may be comparable in mass to the solid iron-cored planet Earth. There is some anecdotal evidence for this; the few times human characters are seen on Cybertron in the animated cartoons they appear to exhibit no difficulty in moving, suggesting the gravity is comparable to that of Earth.

So, what would be the effect of a second planet, of comparable mass, appearing - and given the imagery, this may be optimistic - about ten Earth radii from the core of the Earth? Well, gravitational force (and hence acceleration) scales by Newton's well known  $1$  over  $r^2$  law so at 10 Earth radii, Cybertron would cause an acceleration of the Earth of about  $0.01 g$  or  $10 \text{ cm s}^{-2}$ . Over a long time-scale, this is certainly likely to affect our atmosphere - the kinetic energy required for gas molecules in the outer atmosphere to escape Earth's influence will drop fractionally. The most energetic molecules will escape, and then, as the gas regains equilibrium, their place in the tail of the energy distribution will be taken by other molecules, which will escape in turn. Eventually the atmosphere will be severely depleted - as has already happened on Mars (which has less mass and a lower escape velocity than Earth).

However, a steady depletion of the atmosphere may well be the least of Earth's problems. The Moon has just 1% of the Earth's mass, and lies at 60 Earth radii. The acceleration it induces is less than 0.01% of those we would experience from Cybertron and yet this is sufficient to move the entire bulk of Earth's ocean and cause our daily tides. The tidal forces we'd experience from Cybertron would be many, many times greater! What effect would such strong tides have? Well, we have a good model for this already in the solar system. The planet Jupiter exerts tidal forces on its moon Io sufficient to stretch and compress rock in the same way that our Moon stretches and compresses the oceans - the result is a huge amount of heat generated from friction and pressure, driving vast volcanoes and an ever-changing surface. Long before Earth lost its atmosphere, our air would be polluted by volcanic gases, and the surface would likely be uninhabitable due to an increase in tide-driven tectonic activity. While both animated and film versions of this plot-line do show damage to the Earth, it seems likely these are severely underestimated! It's worth noting that these effects would be reciprocal - Cybertron would be devastated, even as Earth is. Taking a still longer view, the heat and movement generated by those tidal forces robs energy from the orbit - Earth and Cybertron would likely spiral together in a dance of death, ultimately ending in collision and annihilation for both planets. So, all in all, this is one Decepticon plot that may well need a serious rethink.

## Concluding Thoughts

The mass shifting of Cybertronians complicates any calculation of forces or impacts in all versions of *Transformers*, but opens an interesting opportunity to discuss some of the less intuitive aspects of theoretical physics. It's worth noting that the ability of Cybertronians to use 'space bridges' (perhaps a form of Einstein-Rosen worm-hole) and 'transwarp' technology, may well be based on the same underlying perception of higher dimensions as the subspace explanation. One can only hope that the same mass-shifting tech can be extended to the humans who are thrown, dropped, caught and otherwise subjected to rather severe changes of momentum in the course of their adventures.

Other aspects of the *Transformers* multiverse also lend themselves to further analysis. The existence of artificial intelligence and astrobiology of the series, the fascinating insight into the history of computing that thirty years of *Transformers* provides, and communication technology are all potential topics for discussion here on Earth. As long as it exists. Fortunately, across all the *Transformers* incarnations in which Cybertron's move has been attempted, it has never succeeded, thanks to the efforts of Optimus Prime and his loyal Autobots - long may that continue!

## **References and Further Reading**

[http://tfwiki.net/wiki/Transwarp and scale](http://tfwiki.net/wiki/Transwarp_and_scale) - Transformers Wiki

<http://www.badastronomy.com/bad/movies/transformers.html> - Phil Plait's review of the 2007 film

<http://science.howstuffworks.com/real-transformer.htm> - How real transformers work