Physics in motion
Navigating the physics of the transport industry

- The technology that underpins global GPS was first developed by an English physicist at the National Physical Laboratory.
- Physics is enabling faster payments and could facilitate faster travel times through the use of new materials.
In today’s modern and hectic business world, getting people and goods from A to B is crucially important. Whether that’s by plane, train or automobile, technologies based heavily on physics are underpinning much of the transportation industry.

Take current developments in the largest engineering project in Europe: Crossrail. The first sections of the railway, which will carry more than 200 million passengers annually between 37 London stations, are due to open in 2018. Canary Wharf will be one of the flagship stations, playing a vital role in getting workers in and out of the city’s financial district. And, according to Charlie Brooks from engineering firm Arup, physics is vital to the success of its multimillion-pound construction. “The innovative design of the cofferdam (used to hold back the water in Canary Wharf’s North Dock) meant going back to first principles and investigating how the huge lateral and vertical forces can be resolved,” he explained. “Many other aspects of the station design, such as ventilation and electrical engineering, also rely on physics as their basis,” he added. It is estimated that the entire Crossrail project will produce an economic benefit of £42 billion.

Staying in the capital, the technology behind Oyster cards – a way of paying for your journey on trains and buses by tapping a pre-paid card on a reader – has revolutionised travel in London. Seven million cards are used annually to facilitate more than three billion journeys. The technology behind these Oyster cards is radio frequency identification (RFID). Data on how much credit you have are stored on a small chip within the card, which uses the electromagnetic energy that it receives from a nearby reader to transmit information on how much credit is available. The reader then tells the card how much money to debit. The transmission of information happens at radio frequencies of 13.56 MHz and can work over a distance of around 10 cm. The first patent for RFID technology was awarded to US electrical engineer Charles Walton in the 1970s, and research and development in physics has helped to miniaturise the technology over the years and bring RFID into mass production for faster payments across the UK’s transport network.

Physics-based technology is also keeping aircraft safe. In the third quarter of 2012, UK airports saw more than 67.2 million passengers take 554,801 commercial flights, as well as handling 633,015 tonnes of cargo. Overall, the aviation industry contributes £18.4 billion a year to the UK economy and international passengers arriving in the country spend an additional £14 billion. With the skies above us so busy, it is crucial that air traffic controllers have an accurate idea of where the aircraft are. Radar signals are sent into the sky and are detected by a transponder attached to the plane. A message is then returned providing information about the plane’s location, speed and direction. However, the system relies on being able to know that the radar antenna is performing properly.
Previously, radar technology would be tested outside on a range – the antenna would be placed at one end of a field and the radar pattern measured from the other end. Modern techniques now exploit an in-depth knowledge of the relevant physics to make the job easier. One facility where this is done is at BAE Systems’ Advanced Technology Centre in Essex, where they have constructed a 17-sided chamber to test both civil and military antennas. Only the radar pattern produced in the immediate area around the antenna needs to be measured. Then by solving Maxwell’s equations – the physics that governs electromagnetism – a map can be constructed showing what the radar pattern would be like at any given distance and whether it meets the regulations laid down by the aviation industry. “Transforming the near or very-near field data from antennas to give the far-field radiation pattern means that the results of such testing are more accurate. Data can be gathered more quickly, and in all weathers, compared with far-field ranges used for this purpose in the past,” explained Jon Pinto, BAE Systems’ antennas and electromagnetics group leader. “Ultimately, this helps to reduce both the initial and through-life costs of air traffic control radars. Hundreds of millions of pounds worth of antennas are tested this way annually in the UK.”

Transportation in the air, as well as on the ground, has been revolutionised since the Global Positioning System (GPS) became fully operational in 1994. The system relies on more than 24 satellites in orbit around the Earth, which each carry extremely accurate atomic clocks. First developed by English physicist Louis Essen at the National Physical Laboratory in the 1950s, these devices use radiation emitted by caesium atoms to keep track of time. The atomic clocks on board the GPS satellites are accurate to 50 ns (50 billionths of a second). To pin down your location to within a few metres on Earth, a GPS receiver will communicate with at least four of the orbiting satellites and calculate the time that it takes for the signals to come back. Without the accurate atomic clocks that decades of physics research have provided, this wouldn’t be possible.

Without a full understanding of the physics involved, the system would be rendered useless within a day. Albert Einstein’s theories of special and general relativity show that time ticks at a different rate on board the satellites compared with if the clocks were on the ground. This is because the satellites are travelling at speed (about 4 km/s) and they experience weaker gravity from their lofty position. Without correcting for these anomalies, the clocks would lose time by 39 millionths of a second a day. It doesn’t sound like much, but that would equate to a loss of 11 km of location accuracy on the ground. The European Commission and European Space Agency are coordinating the Galileo global navigation system. This project is still in the testing stage and will not be available to the public until at least 2015, but it is designed to be more accurate and robust than current systems.
Physics-based technology helped Tesco transport 2.4 billion cases nationwide in 2012

This GPS technology is now widely used by individuals and industry alike. One such company that relies on GPS technology is UK supermarket Tesco. “We use a vehicle tracking system called Isotrack, which communicates the [GPS] location of every vehicle every 30 s,” said a spokesperson from their distribution team. “Every delivery point, store, warehouse and supplier has a geo-ring fence around it. Once a vehicle breaks this ring fence, a signal is sent back to the team, generating arrival times and ensuring that all parties have the most up-to-date information.” This physics-based technology helped Tesco transport 2.4 billion cases nationwide in 2012.

In the future, as supplies of fossil fuels deplete even further, physics will also have a role to play in finding viable alternatives, from biofuels to solar power, in order to run the next generation of electric and low-carbon vehicles. Research into frictionless transport will make the recently unveiled prototype for a Japanese magnetic levitation train that needs less energy than conventional trains, an everyday sight. When the LO series maglev train goes into use in 2027, it will be capable of hitting a top speed of 311 miles per hour. In November 2012, British company Reaction Engines reported European Space Agency-backed tests of key engine components that could one day see a “spaceplane” revolutionise the travel industry by ferrying passengers from London to Sydney in just four hours. So physics, which has already underpinned the transportation industry for decades, looks set to continue its fundamental role in the transport of tomorrow.

Filling the gaps with nanoparticles

Nanoparticles (particles one-millionth of a centimetre in size) are increasingly being added to aircraft and other vehicles to fill the natural gaps and crevices in their surfaces, no matter how small they appear, to ensure the surface of the vehicle is as smooth as possible. This helps to reduce the drag and increase fuel efficiency. UK company tripleO currently supplies a version of the technology, already used by the US military, to a number of commercial airlines, which not only provides a durable protective coating but also reduces the friction.