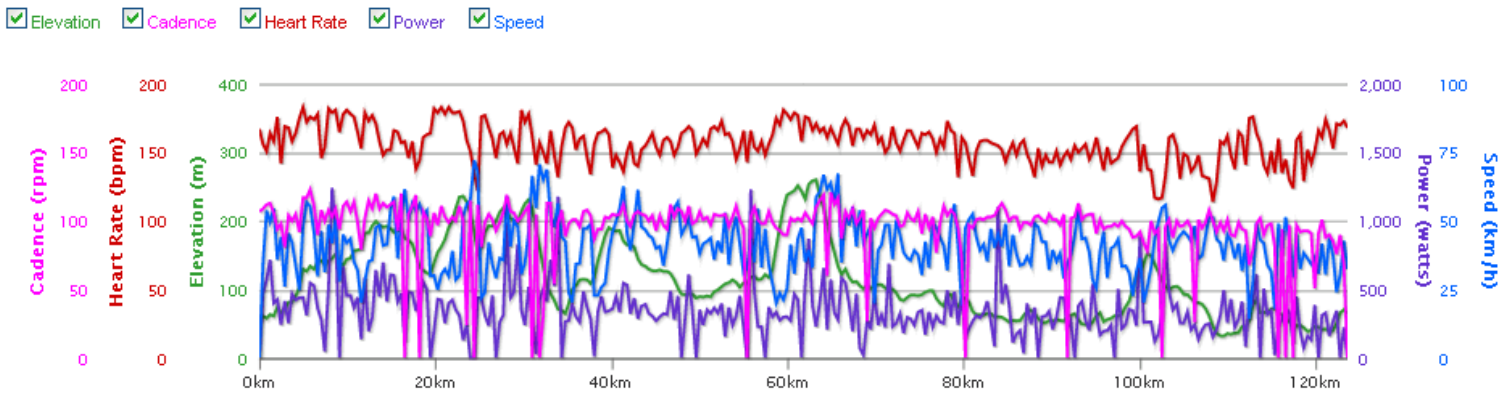
OÉ Gaillimh
NUI Galway

Maths - where is it used in Engineering?



How

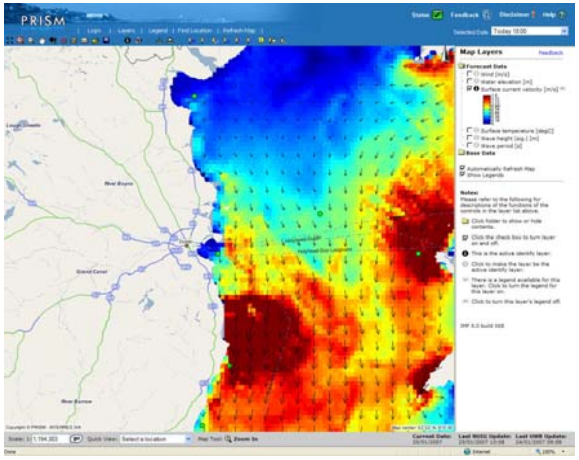
$$j^3 = \sqrt{-1}^4$$

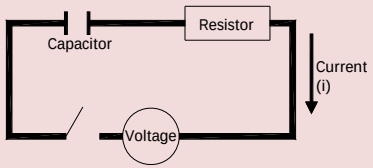
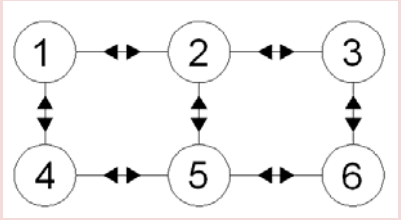
and

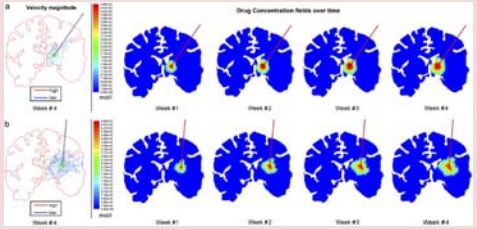
$$u_t + \{u.\nabla\}u = v\nabla^2 u - p_x + f_x$$

are used to measure athletes performance and model the Irish Sea

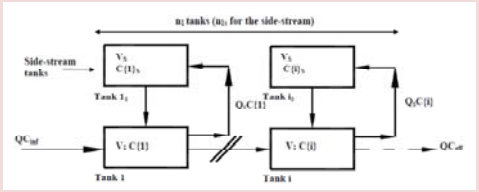
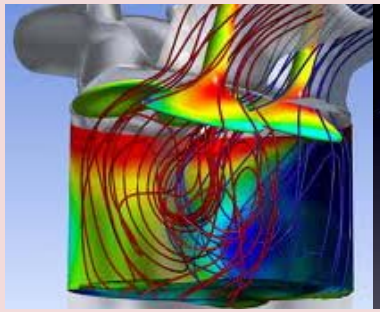
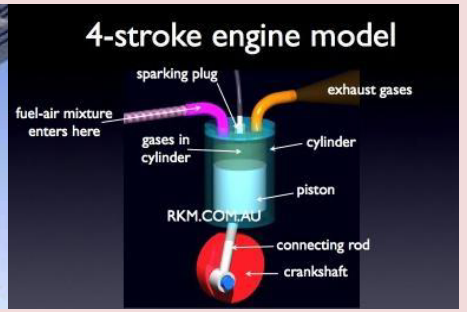
(www.strava.com; www.prism.ie)

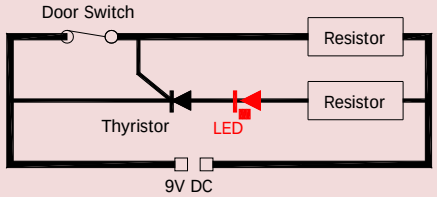
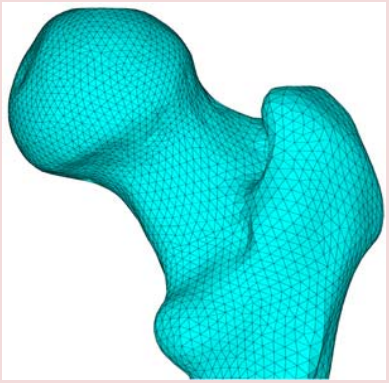
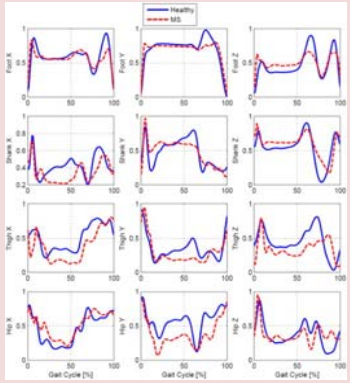


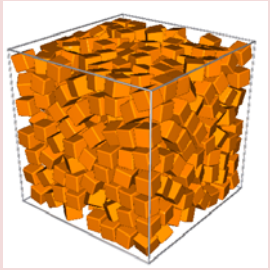
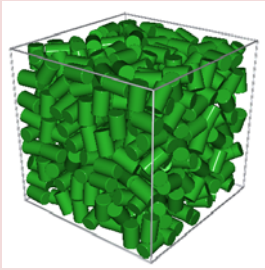
Topic	Engineering Applications	Specific Example
Complex Numbers (incl. De Moivre's theorem)	**<u>Electrical Engineering (A.C. Circuits):</u>** Resistors, inductors, capacitors, power engineering, analysis of electric & magnetic fields and their interactions with materials and structures **<u>Electronics:</u>** Digital signal processing, image processing **<u>Mechanical/Civil Engineering:</u>** Fluid flow, stress analysis **<u>Sports and Exercise Engineering/Biomedical Engineering:</u>** Signal processing and analysis, power meters, heart rate monitors **<u>Energy Systems Engineering:</u>** Design of control systems to protect ocean energy converters at sea	Calculating the voltage, current and impedance (opposition to the passage of a current) in circuits such as the one shown.  **A series RC circuit** Analyse signals from a heart rate monitor and display on a device (such as a computer, or sports watch).  **Heart rate monitors comprise a number of parts. A chest belt transmits a signal to a watch which displays the appropriate heart rate. Monitors must be designed so as not to display interfering signals.**
Matrices and determinants (incl. eigenvalues and eigenvectors)	**<u>Civil Engineering:</u>** Traffic engineering and modelling, structural engineering (trusses), structural engineering **<u>Electrical Engineering (A.C. Circuits):</u>** Electrical networks **<u>Electronic Engineering & IT:</u>** Computer graphics (zoom, rotations, transformations, animation etc), Google search algorithms, Image analysis including facial recognition;	Modelling traffic volumes into and out of specific zones in a city network in order to design new infrastructure. The diagram opposite shows a 6 zone network.  Destination Zone Origin Zone 1 2 3 4 5 6 1 1-2 1-2-3 1-4 1-2-5 1-2-3-6 2 2-1 2-3 2-5-4-1 2-5 2-5-6 3 3-2-1 3-2 3-2-5-4 3-2-5 3-6 4 4-1 4-5-2 4-5-2-3 4-5 4-5-6 5 5-2-1 5-2 5-2-3 5-4 5-6 6 6-3-2-1 6-5-2 6-3 6-5-4 6-5 **A trip distribution model for transport modelling**

	simplification of complex data sets, advanced data and systems modelling, digital communications **Mechanical Engineering:** Mechanics, representation of stress and strain **Energy Systems Engineering:** Predicting emissions of pollutants from next generation jet engines	Design of space frame roof structures. The calculation of forces in members of complex structures uses matrices to design each member.  **A space frame at Parkwest/Cherry Orchard Train Station**
Laplace transforms (solving differential equations)	**Biomedical Engineering:** Analysis of defibrillator systems, drug delivery, fluid flow **Electrical Engineering:** Circuits, power systems (generators), feedback loops (e.g. control of aircraft systems) **Civil Engineering:** Structural design (earthquake engineering) **Mechanical Engineering:** Mechanics of vibrations, fluid flow **Energy Systems Engineering:** Control of battery charging and discharging in electric cars	Determine the concentration of a drug as a function of time and distance from an initial injection site. The diagram opposite shows a model of drug dispersal from 2 initial injection sites  **Drug transport at 2 injection sites**

Statistics and probability	**<u>Civil Engineering:</u>** Flood modelling, water/wastewater treatment **<u>Electronic Engineering & IT:</u>** Designing and modelling the internet **<u>Biomedical Engineering:</u>** Measuring performance of drugs, catheters, prostheses etc **<u>Energy systems Engineering/Civil Engineering:</u>** Wind energy generation, wave height prediction **<u>Electronic Engineering & IT:</u>** Failure rates for semiconductor devices; behaviour of semiconductor materials and structures; image analysis; data compression; digital communications techniques and error correction	Determination of appropriate sites for new wind farm developments. Historical data is analysed using statistics to determine the probability of having a certain wind level on a given day. Statistics are also used to determine where and when power is required within the national grid.  **50-year return periods for high winds in Ireland**
Vector and Trigonometry	**<u>Mechanical Engineering:</u>** Resolving forces in a plane, design of gears (e.g. in cars), design of airplane landing gear **<u>Civil Engineering:</u>** Structural engineering, surveying, traffic engineering, geotechnical engineering **<u>Electrical and Electronic Engineering:</u>** Oscillating waves (circuits, signal processing), electric and magnetic fields, design of power generating equipment, radio frequency (RF) systems and antenna design **<u>Energy Systems Engineering:</u>** Design of sun-tracking mirrors (heliostats) for concentrating solar power plants	Calculate the required height for the landing gear on a jet aircraft with a given take-off angle to ensure a certain tail clearance from the ground (i.e. avoid tail strike). The load on the landing gear can also be calculated using trigonometry and vectors.  **A Boeing 777-200 freighter plane tail strike (Copenhagen Airport, 2011). Changes were made to landing gear design and new computer algorithms developed to prevent pilots increasing pitch if there is a risk of tail strike**

Differentiation/ differential equations (e.g. ordinary differential and partial differential equations, separation of variables, rates of change, Fourier Series)	**Energy Systems Engineering (Mechanical & Civil):** Computational fluid dynamics, modelling of airflow in buildings (for design and temperature control), design of HVAC systems, wave equation for water and seismic waves **Electrical and Electronic Engineering:** Calculation of currents in a circuit, wave propagation, design of semiconductors, Image Analyses (e.g. edge detection) **Civil Engineering:** Hydraulics, conservation of mass equations (e.g. wastewater and water treatment), air pollution models , design of reactor vessels, predicting quantities of materials necessary for construction, design of foundations (soil consolidation), computational solid mechanics **Mechanical Engineering:** Fluid flow, dynamics (motion of projectiles, simple harmonic motion), heat transfer, temperature distribution, combustion (internal combustion engines), computational solid mechanics **General Engineering:** Calculate volumes, areas and lengths of objects, shapes, lines & curves	Design wastewater treatment reactors to remove pollutants before discharge to a river. The size of the treatment system, the amount of oxygen required, pumping requirements can be calculated. The quality of the effluent can also be predicted.   **Modelling hydraulics and contaminant flow in a wastewater treatment plant** Automobile design. Optimise the design of automobile internal combustion systems by modelling pressures in inlet valves, cylinders and outlet valves. These calculations are used to model combustion efficiency and improve power outputs in vehicles.   $\frac{\partial \rho}{\partial \tau} + \frac{\partial}{\partial \varepsilon}(\rho \mu) + \rho E = 0$ **A model of an internal combustion engine. Such models use partial derivates (for example conservation of mass equations).**

Integration (e.g. integration by substitution, integration by parts, partial fractions, root mean squares etc.)	**Sports and Exercise Engineering:** Gait analysis, power meters, design of portable and wearable sensors **Civil Engineering:** Modelling of pollution dispersal, modelling and forecasting of ocean currents, waves and the effect of climate on these, fire engineering **Mechanical Engineering:** Fluid mechanics (e.g. de-icing planes), dynamics (motion of projectiles, simple harmonic motion), mechanics, determination of centre of mass of objects, design of combustion vessels, fuel cells **Biomedical Engineering:** Modelling of internal organs (e.g. model and test medical hypothesis of kidney functions to aid treatment) **Energy Systems Engineering:** Forecasting the effect of renewable energy on reducing greenhouse gas emissions into the future. **Electrical and Electronic Engineering:** Design of thyristor firing circuits (used in power supplies, photographic flashlights, dimming lights, alarm systems, robotics). **General Engineering:** Food processing (design of milk processing systems, production of cheese strings (cooling requirements to ensure bacteria are killed)!	Thyristors are solid-sate semiconductors devices (similar to diodes) that act as switches. They are mainly used to control alternating currents where high voltages and currents are involved. Integration can be used to design thyristors for applications such as shown below.   **Shown above is a simple door alarm circuit with a thyristor. Thyristors are also used extensively in robotics.** The development of new artificial joints is revolutionising medicine and improving patient quality of life. Biomedical engineers design and test these devices. In parallel it is vital these devices work properly when installed in the human body. For example integration mathematics is used to design the optimal shape or calculate stresses in artificial hips.   **A custom designed artificial hip for a patient. Motion analysis can help manufacturers of artificial joints improve their design (shown above is gait analysis data from a multiple sclerosis patient in red with a healthy adult in blue).**

Functions, polynomial, linear equations (Gaussian elimination), inequalities, logarithms, Euclidean geometry (incl. plane intersection)	Almost all engineering problems will use some if not all of these topics. **General Engineering:** Empirical relationships for engineering design, curve fitting, kinetics (biological and chemical reactions), fuel cell design, traffic modelling, power analysis, optimisation of industrial processes (e.g. injection moulding systems), stress analysis, determining the size and shape of almost all engineered parts (e.g. where beams are welded together at an angle they have to be first cut appropriately), software design, computer graphics etc etc.	Companies exporting products incur significant freight costs. Engineers must design products and containers to fit as many units into the smallest possible space. Military engineers use geometry to determine the optimal shape of explosives that can minimise transport costs.   **Comparing shapes for solid propellants used in military hardware. In this example of random packing the cylindrical configuration was shown to be more efficient.**