Maplesoft arilliance tank and the total of total of

351000000

Electrification



Highways

goods, scientists and engineers deploy a wide range of mathematical techniques

rough techniques called mathematical programming, optimization and others, engineers can design highway networks that balance transportation efficiency with resource



One of the first traffic problems

Mathematics Matters in the Modern World

A Brief Look at How Mathematics Has Influenced Modern Life

In 2003, the National Academy of Engineering (USA) published *A Century of Innovation: Twenty Engineering Achievements that Transformed Our Lives*¹. This book celebrates the top twenty technological advances of the twentieth century that fundamentally changed society. These advances have influenced where and how we live, what we eat, what we do for work or leisure, and even how we think about our world and the universe.

Mathematics has played a major role in bringing these innovations to reality. Many mathematical theories and models of real world problems have helped scientists and engineers grapple with seemingly impossible tasks. Today, mathematical techniques reach even further into our society. In addition to making technology more efficient and effective, mathematical techniques help organizations deal with financial, manufacturing, and even marketing issues.

This poster is a tribute to the National Academy of Engineering as well as the men and women who have focused their brilliance to transform the modern world. The poster is a mosaic of the ways mathematics helps us utilize and benefit from these great technological achievements. Some achievements will be familiar. Some will be a surprise. All, hopefully, will encourage you to investigate these topics further

About Maplesoft™

Maplesoft is proud to sponsor this public service poster. As a leading provider of software tools for mathematical applications, research, and education, we feel that the promotion of mathematics itself is equal as important as the promotion of our technologies. For more information on how Maplesoft products such as Maple helps modern engineers and scientists manage their mathematics, visit www.maplesoft.com.

George Constable and Bob Somerville, A Century of Innovation: Twenty Engineering Achievements That Transformed Our Lives (Washington: National Academies Press, 2003).

The content on this poster does not necessarily reflect the position or views of the National Academy of Engineering, and no official endorsement should be inferr

www.maplesoft.com

Maplesoft

www.maplesoft.com | info@maplesoft.com

Maplesoft, a division of Waterloo Maple Inc., 2006. Maplesoft is a trademark of Waterloo Maple Inc. All other trademarks are the property of their respective owners

Nuclear Technology



E=mc² is the world's most famous equation. Introduced by *Albert Einstein (Swiss, 1879-1955)* in 1905, it tablishes the relationship of energy and matter. Einstein, along with major contributions from his contemporaries Iding Bohr. Heisenberg. Rutherford. and Fermi.

dramatically increased science's understanding of the nature of atoms and atomic energy. Einstein, himself, had no direct involvement with the development of the atomic bomb.

Einstein was also notable for his early adoption of tensor notation, which offered more efficient manipulation of multidimensional equations The following is a simple example of compact tensor notation for a vector

$\mathbf{u} \cdot \mathbf{v} = u_i \, v_j \, \delta_{ij}$





 $\mathbf{v} = \sum_{j=1}^{\infty} v_j \mathbf{e}_j$ $\mathbf{u} \cdot \mathbf{v} = \sum_{i=1}^{3} u_i \mathbf{e}_i \cdot \sum_{j=1}^{3} v_j \mathbf{e}_j$



 $= u_i v_j \left(\mathbf{e}_j \cdot \mathbf{e}_i \right)$ $= u_i v_j \delta_{ij}$

Marie Sklowdowska Curie (Polish, 1867-1934) discovered the new elements polonium

Gregorie-Ricci Curbastro (Italian, 1853-1925) invented tensor calculus. Tensor

calculus and tensor algebra are

essential tools in many fields of

engineering, including fluids and so

mechanics, and in modern physics.

these subjects are critical to the safe

and effective management of nuclear

and radium. Her work deepened our understanding of radioactive materials, which ultimately lead to the development of nuclear energy technology. Curie also pioneered the use of radiation for cancer treatment.

 $\mathbf{u} = u_x \mathbf{i} + u_y \mathbf{j} + u_z \mathbf{k}$



over all seven bridges without crossing over any

Radio & TV

Signal processing is one of the most important mathematical fields that supports the design and effective operation of radio and TV.

Amplitude Modulation (AM) is the earliest form of radio transmission. applies a simple combination of a carrier wave and a modulating wave (the message). For example, a carrier wave is,

 $c(t) = C \sin(\omega_c t)$ The signal that we wish to broadcast could be

 $m(t) = M \sin\left(\omega_m t + \varphi\right)$ The modulated signal is then

$y(t) = (C + M\sin(\omega_m t + \varphi)) \sin(\omega_c t)$ 0 1 2 3 4 5 6 7 8 9 10

Frequency Modulation (FM) uses the modulating signal to vary the requency of the carrier signal. FM signals are generally more robust and are capable of carrying higher fidelity signals.



Claude Shannon (American. 1916 – 2001) roduced Information Theory in 1948. Information Theory mathematically predicts the amount of information contained in a signal and the ability of a channel to transmit this information. One of his equations states that the capacity of a channel (how much information can be transmitted) is given by

 $C = B \cdot \log_2(1 + S/N)$

where B is the channel bandwidth and S/N is the signal-to-noise ratio of the channel. This type of analysis was instrumental in improving the quality of communication systems and even other branches of computer science and engineering such as image processing, data mining, and pattern recognition. Today we see Shannon's legacy in virtually

all aspects of the Information Revolution.





Electronics

The invention of the transistor in 1947 at Bell Labs launched the electronics age. This small, three-terminal device allows current to flow between two of its terminals depending on the current or voltage applied on the third. It can be used for amplification, switching, modulation, and many other tasks that had only been possible by large, less robus vacuum tubes or mechanical relay switches. Over time, transistors

pecame further miniaturized within integrated circuits (chips). Sample mathematics of a Bipolar Junction Transistor (Ebers-Moll model) $I_{\rm F} \rightarrow \leftarrow I_{\rm FD}$ $I_{\rm ED} \rightarrow \leftarrow I_{\rm C}$ Emitter current Collector current $= \alpha_{E} I_{ES} | e$ Base-internal current -q D p $J_P(Base) =$ Where is the common base forward short circuit current gain (0.98 to 0.998)

- is the reverse saturation current of the base-emitter diode (on the order of 10^{-15} to 10^{-12} amperes)
- is the thermal voltage (approximately 26 mV at room temperature ≈ 300 K)
- _{BF} is the base-emitter voltage W is the base width



Computers



Boolean algebra, the mathematical foundation of the logic used by the digital computer. In particular, computers use the special case of Boolean logic where entities can have only two values (e.g. 1 or 0, the bina system) and a set of clear rules defines their operations.

If X is true and Y is false, or X is true and W is true, then Z is true" is a typical decision that computer programs make. In Boolean mathematical form, this decision would look like:



0002

Ada Byron, Countess of Lovelace (English, 1815-1852) was the world's first computer programmer. She wrote a brilliantly detailed account of the functioning and potential of Charles Babbage's Analytical Engine. Her work became a foundation for modern concepts of computer programming. The rogramming language Ada honors her work.

Alan Turing (British, 1912-1954) is often considered the father of moderr computing. He developed seminal concepts for the design and function of modern computers. The Turing Test was his proposal for assessing the true

Water Supply **& Distribution**

iseases by disinfecting water has been recognized since the early 900's. Of the existing processes used to produce safe drinking water hlorination of public water supplies ranks as one of the most important.



Computers Doing Math

The idea of a machine to do mathematical calculations is not modern at all. Pascal, Leibniz, and Babbage are well-known for their attempts at automating calculations long before Microsoft[®], Apple[®], or Intel[®].

Blaise Pascal's machine (1652) could add or subtract numbers. lis most advanced models could work with numbers up to 9,999,999.



o-father of calculus *Gottfried Leibniz* also designed a machine (1671) that could perform addition, subtraction, nultiplication and division

arles Babbage designed Difference and Analytical Engines capable of more advanced calculations. They also featured programming through hole-punched sheets.

Today, a modest machine with the right software can crunch

rough math that would have taken a hundred *Gausses* a hundred years to do. Spreadsheets help business people use math to make business decisions. Advanced software like *Maple* replicates the mathematical thinking that is needed to build a spacecraft or cure a disease.



Modern imaging relies heavily on digital image manipulation. The algorithms to enhance pictures or to automatically ect items in pictures are all inherently mathematical.





or image processing, we require a two-dimensional variation.



Euclid of Alexandria (*Greek*, 325 – 265 BC) wrote the earliest book on Geometric Optics (300 BC). His principles still survive today. f light-ray

Fourier Transforms (FFT) are versions of the general Fourier Transforms where the mathematics is broken into cretized) to allow efficient computation on computers



 $Z = (X \cdot Y) + (X \cdot W)$

Household Appliances

Statistical Process Control (SPC): William Edward Deming (American, 1900-1993) was a pioneer of Statistical Process Control (SPC). He led the

ble technology enters our home via household SPC uses statistical techniques to measure and manage the quality of manufactured consumer items such as househol appliances. Innovative use of classical mathematics has dramatically increased factory productivity and lowered



Measuring the market: Auguste Compte (French, 1798-1857 vas a leading force in the 19th century movement called *Positivism*, which saw athematics and statistics as valuable tools

n making decisions about people and society. Today experience his legacy in business practices that use to model consumer behavior and determine keting tactics for persuading us to buy to an innovative global household appliances and other items.

00 000

me measured in trading days from initial

Almost 65 years later, Bachelier's

deas were taken up with

prize-winning economist

nust fluctuate randomly. H

he basis of what is now kr

Paul Anthony Samuelson

nerican. 1915). who argued that discou

e "efficient market hypothesis", whic

olution in empirical finan

ignificant effect by the Nobel

e increment of Brownian motion.

Ktdt is the size of the predicted



Airplanes

Navier-Stokes equations are partial differential equations that descr notions of fluids (liquids and gases). In addition to airflow analys airplanes, they are useful for modeling weather, ocean currents and many other systems. A simplified form of these equations within a artesian frame of reference is as follows:















Archimedean treatment of the lever



L =length of effort arm = length of resistance ar

- R = resistance weight or force
- E = effort force

Petroleum & Petrochemicals



5 10 15 20

- LCL = 0.18, UCL = 8.54

- CL = 9.36

Telephone



Agner Krarup Erlang (Danish mathematician, was the first tr of telephone networks in 19 unit named the Erlang is r telecommunications trad

rlang's Formula:



C is the number of lines, with an average of v (



d in the long term, the greatest single for influencing petroleum prices is the cos f crude oil. As such, its trading activity is elv watched and routinely scrutinized.

e first successful attempt to model of Speculation". Bache

etric Brownian M

The Internet

Part of the growth of the internet has been due to mathematical techniques designed to maintain privacy and authenticity of information. Cryptography mathematical science behind the encryption schemes that do this.

Modern cryptography is highly mathematical, utilizing advanced number theory and complexity theory, among other fields.



Julius Caesar (Roman, 100 BC – 44 BC) used encryption to

The RSA (Rivest-Shamir-Adleman) algorithm is an example of a publ key encryption algorithm that offers an elegantly simple way of storing and sharing the keys needed to unlock sensitive information. RSA is the main algorithm behind the security infrastructure that we use on the Web. The math in RSA centers around the difficulty in factoring large integers, that is, to defeat an RSA scheme you must be able to solve a virtually impossible factoring problem.

n = pq (p and q are distinct, typically large prime numbers)

Choose *e* such that *e* is relatively prime to *m*, that is, no number other than 1 divides into *e* and *m*.

Find d such that $de \mod m = 1$. If p and q are large, solving for d by break the key is virtually impossible.

> This number d is part of the secret (or private) key that unlocks hidden information. The number e is part of the public key that allows others to lock up information destined for specific people.

Another important public key algorithm uses elliptic curves over a finite field to supply the impossible problem. T advantage over RSA is that smaller numbers can be used with equal security. This is important for mobile devices where speed and space are issues.



communicate with his generals. Named after its first recorded use the *Caesar cipher* shifts each letter of a message by a constant number of letters. The constant is the "key".

m = (p-1)(q-1)



Spacecraft

Although the science and mathematics behind space exploration is n boggling, many key concepts relate back to the fundamentals that many of us are familiar with. For example, modern orbital mechanics calculations still rely directly on the work of Kepler and Newton, among others.

scientists have used a variation of his method called the Hidden Markov Model (HMM) to decipher the mappings and interactions within the genomes of living organisms.



High Performance Materials

commonly known as plastics. A new invention of the 20th century, they are now found everywhere in a wide variety of forms.

One application of high performance plastics is the artificial lung

Fick's First Law of Diffusion: $J = -D \frac{\partial \phi}{\partial \phi}$

Steady-state diffusion Fick's Second Law of Diffusion: $\frac{\partial \phi}{\partial \phi} = D \frac{\partial^2 \phi}{\partial \phi}$

Max Karl Ernst Ludwig Planck (German, 1858-1947) is considered to be the founder of quantum theory, and is regarded as one of the most important physicists of the twentieth



Amalie Nöther (German, 1882-1935) stablished Nöther's theorem, a central esult in theoretical physics that expresses he one-to-one correspondence between symmetries and conservation laws. It is deeply tied to quantum mechanics.

is the compressio

Rudolph Diesel (*German, 1858-1913*) invented the Diesel engine that applied a different thermodynamic cycle

(and fuel) than the Otto cycle

