

BPhO

Computational Challenge

Introduction

Dr Andrew French.
December 2021.

- Register via <https://www.bpho.org.uk/>
- **11 x 1 hour weekly seminars** Jan-April via Zoom, delivered live. Course content (slides, homework problems, code) available at the [BPhO website](#) and via [Dr French's Eclecticon](#).
- Annual ***Challenge*** to be set after April-Sept. **Bronze**, **Silver** and **Gold** standard problems, so you can choose your level.
- The ***Challenge*** can be attempted individually or in pairs, and you are free to use any appropriate spreadsheets or programming languages. In the course, students will have direct experience of Microsoft Excel, MATLAB and Python.
- Submit your ***Challenge*** entry via a hyperlink to a ***two-minute unlisted YouTube video***, i.e. a 'screen-cast' which describes your solution(s) to the Challenge tasks. The Chrome browser add-on [Screencastify](#) is a recommended tool.



Why are we doing this?

Think of a modern profession that *does not* involve the use of computers to create, record and store information, control machinery I'm not sure I can.

Experience of **data flow, data processing** and **information presentation** is a particularly vital element of scientific craft. But at the moment your Science experience is probably mostly theoretical problem solving, taking notes and performing lab experiments.

Real Scientists will spend most of their time on data flow, data processing and information presentation. **So start learning these skills and you are more likely to get a job.** The likes of Amazon, Google, Uber, Facebook will continue to 'disrupt' traditional industries. **If you don't have these skills, you will not have much to offer to the higher paid sectors of the economies of the future.**

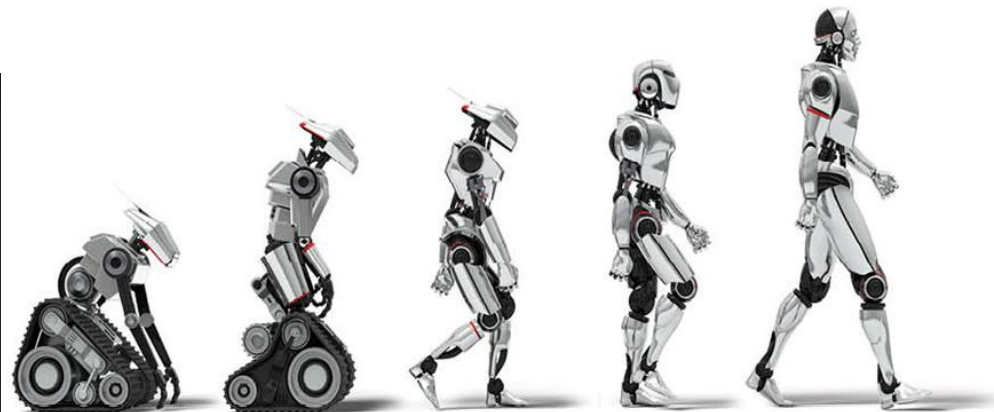
But even if your horizon is merely "how can a get a Distinction at A-Level and get into a top flight University?" skills in Scientific Computing are a great way to consolidate your subject, especially when you **begin to create projects and systems of your own design.**

***Making things yourself* is the BEST motivator for learning**



If most future jobs currently performed by humans will be done much more efficiently and safely by robots / artificial intelligence...

*Wouldn't **you** want to be the person programming this technology?*



<https://robohub.org/envisioning-the-future-of-robotics/>

BPhO Computational Physics course content (weeks 1 – 5)

- 1. ERRORS.** Incorporating experimental uncertainty in calculations. Presenting calculations clearly using spreadsheets and code scripts.
- 2. DATA PROCESSING PIPELINE.** Pendulum period vs length data in Excel. Linearize and compare model to data via a line-of-best fit. Find g +/- error. Automation of the data processing pipeline in MATLAB.
- 3. LINES OF BEST FIT.** Mathematics of linear regression i.e. recipe for finding m and c for an optimum $y = mx + c$ fit to a (linearized) data set, and errors in m and c . Also $y = mx$ fit
- 4. CHERNOBYL.** Recap of a data analysis pipeline using a radioactive decay scenario. Scatter graphing in Excel. Determine background noise level. Linearization & line of best fit. Parameter estimation (i.e. half-life, initial activity) + errors. Automation in MATLAB.
- 5. WEATHER.** Analysis of moderate to large amounts of data using the example of meteorological measurements recorded since 2018 via an automated system on the roof of Winchester College Science school.

BPhO Computational Physics course content (weeks 6 – 11)

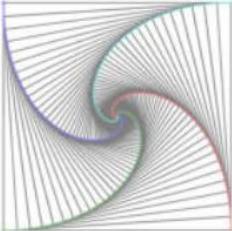
6. **THE PLANETS.** *Kepler's Third law* for Solar System. Compare to *Exoplanets*
7. **NUMERIC CALCLUS.** Numeric methods to solve differential and integral Calculus problems.
8. **GRAVITY & VERLET.** Use of the *Verlet method* for: (1) 1D ball drop (and bounce), (2) Projectile motion with drag, (3) Orbital motion.
9. **RANDOM WALKS.** Idea of *mean free path*, *Knudsen number*, *diffusion*. 1D random walk displacement proportional = step size $\times \sqrt{(\# \text{ steps})}$. Extension to 2D and 3D.
10. **CHAOS.** *May's population model*. r parameter results in extinction, stability, oscillations, and ultimately a progression to *chaos* via a cascade of *bifurcations*.
11. **EPIDEMIOLOGY.** Mompesson's S, I, R, D data for Eyam Plague in 1666. Estimate α , β , R_0 parameters that characterize the epidemic in this *closed system*. Can we apply the model to other diseases such as Ebola and Coronavirus?

then ***CHALLENGE***

Recommended text for the course:

Home Art Books Comedy Films Fitness Gastronomy Maths

First created July 2012
Last updated Aug 2021



SCIENCE BY SIMULATION


Dr Andrew French andy.french@physics.org www.eclecticon.info/scibysim.htm

Volume 1: A Mezze of Mathematical Methods

Volume 2: Models of Classical Physics

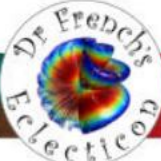
Volume 3: Models of Modern Physics

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Mountaineering Music Philosophy Photography Physics Programming Writing



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Art Books Comedy Films Fitness Gastronomy Maths

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Volume 1: A Mezze of Mathematical Methods

[Science, Models and Maths](#)
[Election Cups](#)
[Snails of Pursuit](#)
[The Epidemiology of Eyam](#)
[Holmes & Watson meet Bayes](#)
[May's Chaotic Bunnies](#)
[Pendulums and Strange Attractors](#)
[A Standard Atmosphere](#)
[The Subtlety of Rainbows](#)
[Exploring Julia's Fractals](#)
[Radar, Chirps and Phased Arrays](#)

[Navigating the Sphere](#)
[Modelling Money and Mortgages](#)
[Power to the People](#)
[Linear Regression](#)
[Euler and Runge Kutta methods](#)

Download all the code for the book

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Volume 2: Models of Classical Physics

Problem solving, practical experiments and computer simulations
Mechanics (Bouncing balls, Projectiles, Statics, Rolling, Lagrangians)
Thermodynamics (Heat engines, Newtonian cooling, Kinetic theory, Boltzmann)
Waves and ray optics (Standing waves, Refraction, Reflection, Lenses, Mirrors, Diffraction, Doppler & Mach, water waves & Kelvin Wedge, SHM)
Electromagnetism (Resistors, Dipoles, Ferromagnetism and the Ising model, Fresnel Equations, LCR circuits, Maxwell's equations)
Calculus of Variations
Interfacial waves

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Volume 3: Models of Modern Physics

Nuclear & Quantum (Atoms, Rutherford scattering, Planck spectrum, Photoelectric effect, Electron diffraction, Bohr's quantum atom, Schrodinger Equation and Particle in a Box, Uncertainty Principle, Measurement and Malus, Radioactive decay, Nuclear binding energy)
Special Relativity (Time dilation, Length contraction, Loss of simultaneity, Lorentz transform, Twins paradox, Minkowski spacetime, Velocity transforms, Doppler effect, $E=mc^2$, Relativistic dynamics, Compton scattering)
Orbits of stars, planets and moons
(Gravitational fields, Escape velocity and Black Holes, Kepler's Laws, Orbit simulations, Tidal forces, Hubble's law and the Big Bang)

Download all the code for the book


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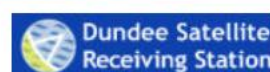

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Additional online materials: <http://www.eclecticon.info/physics.htm>

Home | Art | Books | Comedy | Films | Fitness | **Physics** | Gastronomy | Maths


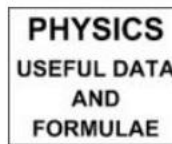

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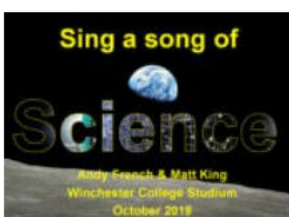
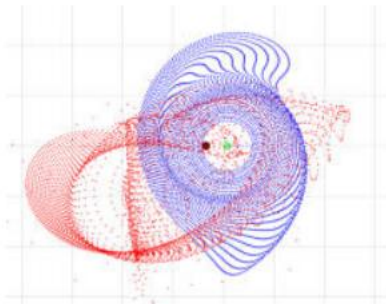

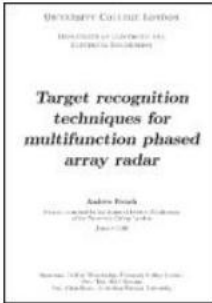
HYPERPHYSICS
▶ Science wars

Experiments Questions Publications

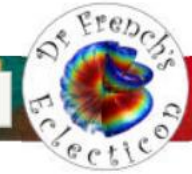
  Simulations 

Notes Courses

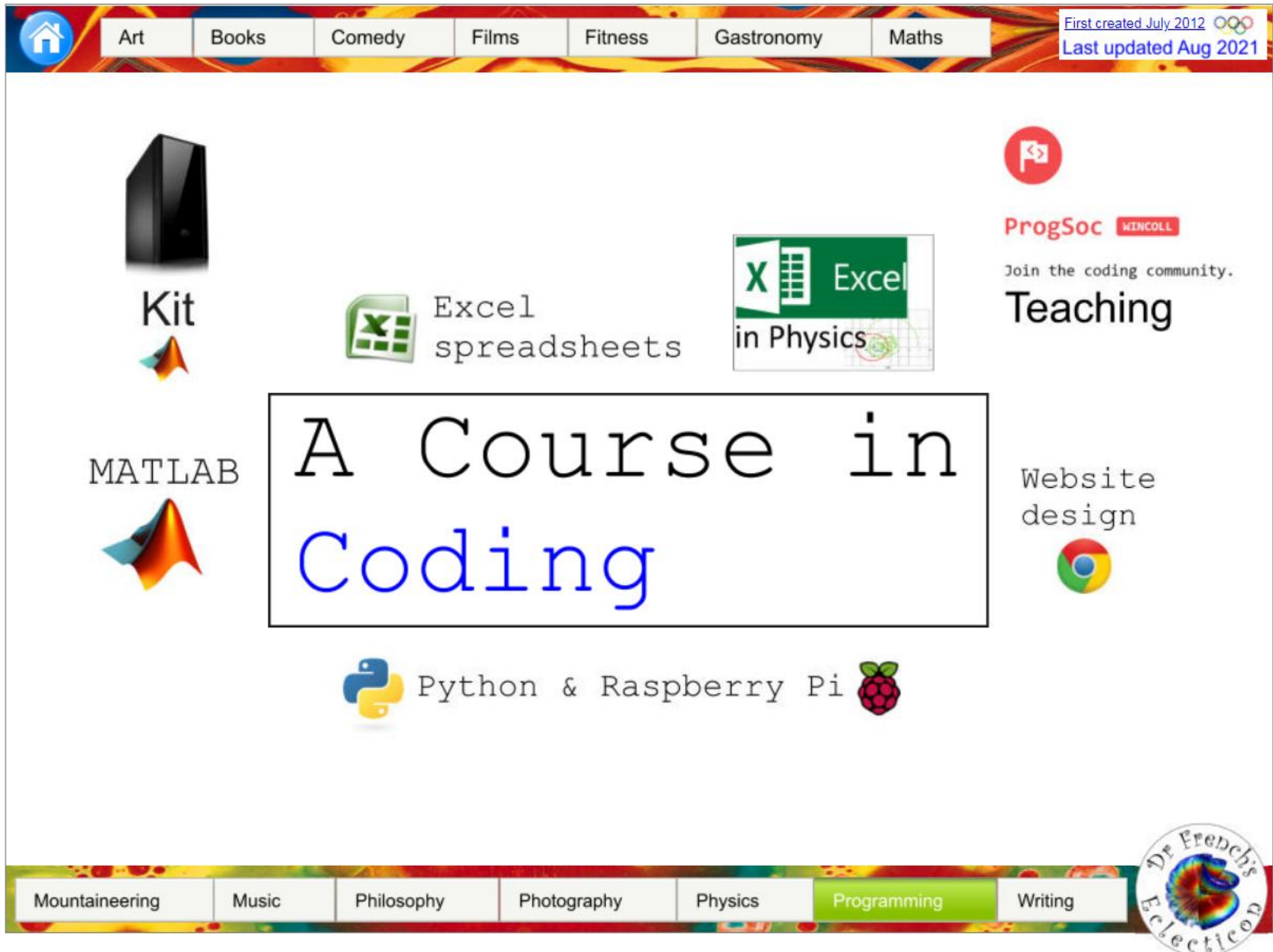
The Science of Christmas


Mountaineering | Music | Philosophy | Photography | **Physics** | Programming | Writing



Additional online materials: <http://www.eclecticon.info/programming.htm>



The image shows a screenshot of the website <http://www.eclecticon.info/programming.htm>. The page features a navigation bar at the top with categories: Art, Books, Comedy, Films, Fitness, Gastronomy, and Maths. A home icon is on the left, and a date stamp on the right indicates it was first created in July 2012 and last updated in August 2021. The main content area is centered around a large box containing the text "A Course in Coding". Surrounding this central text are various icons and logos for related topics: a computer tower labeled "Kit", a spreadsheet icon labeled "Excel spreadsheets", the Microsoft Excel logo labeled "Excel in Physics", the MATLAB logo, the ProgSoc logo with the text "Join the coding community. Teaching", the Google Chrome logo labeled "Website design", and the Python logo with a Raspberry Pi icon labeled "Python & Raspberry Pi". At the bottom, a secondary navigation bar includes categories: Mountaineering, Music, Philosophy, Photography, Physics, Programming (highlighted in green), and Writing. The Eclecticon logo is visible in the bottom right corner.

Home | Art | Books | Comedy | Films | Fitness | Gastronomy | Maths | First created July 2012 | Last updated Aug 2021

Kit

Excel spreadsheets

Excel in Physics

ProgSoc WINCOLL

Join the coding community.

Teaching

MATLAB

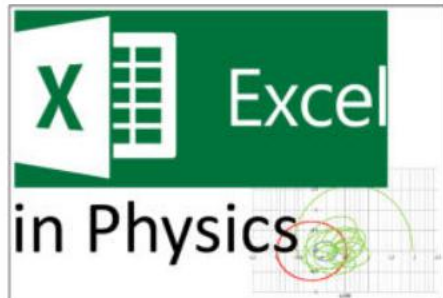
A Course in Coding

Website design

Python & Raspberry Pi

Mountaineering | Music | Philosophy | Photography | Physics | Programming | Writing

De French's Eclecticon



▶ Intro

[Project vs skills matrix](#)

Simple calculators

SPEED CONVERTER

SPEED IN METRES PER SECOND: 20

SPEED / KM PER HOUR: 72.00

SPEED / MILES PER HOUR: 44.74

SPEED / NAUTICAL MILES PER HOUR: 38.88

SPEED / NANOPARSEC PER BEARD-INCH: 2.94

$\text{nanoparsec} = 10^{-9} \times 3.086 \times 10^{16} \text{m} = 6.80 \text{ms}^{-1}$
 $\text{beard-inch} = 7.5 \times 7 \times 24 \times 3600 \text{s}$

$\text{speed} = \frac{\text{distance}}{\text{time}}$
 $\text{mile} = 1609 \text{m}$
 $\text{nsmile} = 1852 \text{m}$
 $\text{ms}^{-1} = 2.237 \text{mph}$
 $\text{ms}^{-1} = 3.600 \text{kmh}^{-1}$
 $\text{parsec} = 3.086 \times 10^{16} \text{m}$
 $\text{beard-inch} = 7.5 \text{weeks}$

[Speed converter](#)
[Snell's law of refraction](#)
[Radio frequency & wavelength](#)

Maths tools

ERROR CALCULATION

ACTUAL X VALUE: 122

X VALUES WITH RANDOM ERROR: 121, 121, 125, 122, 120, 128, 120, 121, 124, 119

MEAN X: $\bar{x} = \frac{\sum x_i}{n}$

ERROR IN X: $\sigma_x = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n}}$

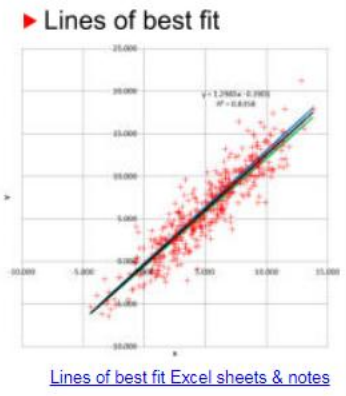
SO: $x = 122 \pm 3$


▶ Error analysis
[Errors Excel sheet](#)

- Excel techniques:**
- [How to videos](#)
 - [Number & text formatting](#)
 - [Formulae & replication](#)
 - [Using \\$ prefix constants](#)
 - [Plotting scatter graphs](#)
 - [Underlying model curves](#)
 - [Lines of best fit](#)
 - [Plotting error bars](#)
 - [IF statements in formulae](#)
 - [Printing to PDFs and PNGs](#)
 - [Dealing with lots of data](#)
- [Solar system Excel sheet](#)

- Virtual experiments**
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 - [Ball vs parachute](#)
 - ▶ [Faraday's law](#)
 - [Solar System](#)
 - [Ball projectile](#)
 - ▶ [Beta decay of Protactinium](#)
 - [Hubble's law](#)
 - [Exoplanets](#)
 - ▶▶ [Capacitor discharge](#)

- Simulations**
- [1D gravity + drag](#)
 - [Epidemics](#)
 - [2D projectiles + drag](#)
 - [1D water rocket](#)
 - [Orbits & galaxies](#)
- 



 A Course in Coding

All the downloads are .zip files. To edit the Excel sheets you will need to extract them to one of your own personal folders

[Download the whole course \(85.1MB\)](#)