The Calculess Engineer!

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Why teach calculus to engineers? A question one would be tempted to dismiss as silly were it not actually being asked; and it is being asked, so I was led to believe at the LTSN MathsTEAM workshop which preceded the Mathematical Education of Engineers conference in Loughborough back in April 2003.

If the question is serious why was my first instinct to dismiss it out of hand?

Well, I work for the Naval Marine part of Rolls-Royce, in an engineering environment, and I seem to use calculus all the time! For example, I've produced mathematical models of heat transfer and fluid flow systems for use in design, performance and safety studies of nuclear reactor plant. The conservation laws of mass, energy and momentum, called upon in the development of such models, are expressed in terms of differential equations. I've developed models of the concentration of chemical species in porous deposits, where the chemical rate equations, as well as the heat transfer and fluid flow, are expressed as differential equations. Differential equations are everywhere in an engineer's world: transport phenomena, chemical processes, vibration, stressing … the list is endless. It's difficult to understand them if you know no calculus!

I've developed algorithms for position correction of multi-segment refuelling lids, where a hole in eccentrically layered circular rings has to be positioned over points on a square lattice via multiple angular rotations. Development of such an algorithm requires the ability to differentiate trigonometric formulae (alternatively, a perturbation technique is possible; but I suspect that an engineer who knows no calculus is unlikely to be too hot on perturbation methods either!).

As a final personal example, I've developed algorithms for extracting surface conditions, such as roughness, from optical measurements of components. These require the ability to integrate a curve (both numerically and analytically) and to understand the physical significance of the resulting measures.

Am I a typical engineer? No, I'm a mathematical modeller. So perhaps the engineers themselves don't need to know the calculus that I must use.

If you agree with this statement you are conforming to a widespread public perception of engineers, and confusing engineers with fitters. Engineers must *understand* what they design. They are *responsible* for ensuring their products are cost-effective, safe and fit for purpose. This means they must have some comprehension of the basis of any models and tools they use in generating their design. They can't abdicate all but a handle turning involvement with the calculational tools of their trade. Understanding and responsibility come from knowledge, not ignorance.

Surely though, most of the relevant knowledge is embedded within the major computer programs used these days? Stress men use well-respected codes like ANSYS or ABAQUS; computational fluid dynamicists have FLUENT and CFX; more general calculations are done with widely available tools like MATLAB and MATHCAD. Engineers can be confident in the output from these codes.

Well, even if true, engineers should no more abdicate to a piece of software than to a mathematical modeller! But, of course, it isn't automatically true. A blind belief in the output of models constructed in any of the above, or other, codes is naïve. Engineers can spend a lot of time and effort in verifying and validating computer model calculations; because experience dictates the calculations are rarely right first time! Because validating against reality is usually time consuming and costly, the engineer never has all the validation information he or she really wants. It is therefore imperative that he/she understands enough of the mathematical underpinning of the model to be confident in its predictions over the full range of conditions the relevant component/system/process will experience.

Clearly, engineers need to know more mathematics than just calculus (indeed, I suspect that difficulties with calculus reflect an underlying and even more worrying difficulty with algebra), but a knowledge of calculus *is* important for engineers.