The Editor welcomes letters, by e-mail to ped@iop.org or by post to Dirac House, Temple Back, Bristol BS1 6BE, UK.

Measuring inductance and capacitance

I have four comments on Mak's very useful article on 'Six ways to measure inductance' (*Phys. Educ.* **37** (2002) 439–45).

Firstly, in Mak's Method 1 of measuring inductance using an a.c. *RL* series circuit, the exact equation, derived from Mak's equation (1), for the inductance is

$$L = \frac{RV_L}{\omega\sqrt{V_Z^2 - V_L^2}} \qquad (1)$$

where V_Z is the amplitude of the sinusoidal source voltage of angular frequency ω, V_L is the amplitude of the voltage across the inductor and R is the resistance of the resistor. Equation (1) above, which is valid for all relative values of R and the inductive reactance ωL, is already simple. Hence, it is not necessary to impose the restriction $R \gg \omega L$ as Mak did to simplify the equation for L.

Secondly, using the relationship $V_Z^2 = V_L^2 + V_R^2$, where V_R is the amplitude of the voltage across the resistor, equation (1) can be rewritten as

$$L = \frac{R\sqrt{V_Z^2 - V_R^2}}{\omega V_R} \qquad (2)$$

or

$$L = \frac{RV_L}{\omega V_R}. \qquad (3)$$

So, in Method 1, the inductance can also be determined if V_Z and V_R are measured, or if V_L and V_R are measured. Mak noted the former possibility but not the latter.

Thirdly, in Mak's Method 3, if the maximum slope of $V_R(t)$ versus t instead of $V_Z(t)$ versus t is measured, then the inductance can be determined from the exact equation

$$L = \frac{RV_L}{[\mathrm{d}V_R(t)/\mathrm{d}t]_{\max}} \qquad (4)$$

where there is no restriction on the relative size of R and ωL, rather than from the approximate one, Mak's equation (5), which is valid only for $R \gg \omega L$.

Finally, all six methods of measuring inductance can easily be adapted to measure capacitance. The standard method of measuring capacitance is based on the exponential decay of the voltage across a capacitor while it is discharging, analogous to Mak's Method 4 of measuring inductance. For the capacitive analogue of Mak's Method 1, replace the inductor in the circuit by a capacitor. Like the inductance case where there are three equations for the inductance, there are also three equations for the capacitance

$$\begin{aligned} C &= \frac{V_R}{R\omega V_C} \\ &= \frac{\sqrt{V_Z^2 - V_C^2}}{R\omega V_C} \\ &= \frac{V_R}{R\omega\sqrt{V_Z^2 - V_R^2}} \qquad (5) \end{aligned}$$

where V_C is the amplitude of the voltage across the capacitor. So, to determine the capacitance, we could measure either V_R and V_C, or V_Z and V_C, or V_R and V_Z in the a.c. *RC* series circuit. I leave it to the interested readers to work out how Mak's other methods can be adapted to measure capacitance.

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Physics education and the environment

There are proposals that science education should provide a school-level introduction in certain topics of concern in contemporary applied science. In particular it is supposed that children should be taught more about environmental issues such as the greenhouse effect. Such a policy is misguided and will almost certainly cause grave harm.

- The function of schools should be to give clear, systematic education in the principles of subjects. This should provide information and understanding that may be of value to citizens for the rest of their lives. As far as the abilities, interests and opportunities of pupils permit, what they are taught should be of value in 50 years' time.
- Great damage has been done to science education during the past generation by the imposition of ideas relating to contemporary obsessions. The absurd belief that teaching 'something about atoms' would somehow prevent a nuclear war led to very inaccurate teaching of advanced ideas which has done lasting grave damage to education in chemistry and physics. A rise

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in the price of oil led to obsession with 'the energy crisis'. This contributed to the misrepresentation of the scientific concept *energy* both in schools and in popular science.

Rational concern about the effects of pollution has been replaced by apocalyptic distortions. Children have been upset, even terrified, by the image of wicked scientists, manufacturers etc destroying our planet. This has helped to create distress and hostility to science.

- There is a widespread idea that advanced scientific topics can be taught in isolation without any preliminary preparation by more elementary teaching. In consequence children are being misinformed and confused by the presentation of concepts that are beyond their understanding. Indeed, much that is taught is demonstrably beyond the understanding of the teachers and those who teach the teachers.

  Before any topic is added to the curriculum it is essential to establish what more basic knowledge is needed for its understanding. It is then necessary to discover how far this foundation is known to teachers and provided accurately in textbooks and other sources.
- It appears that one motive for the proposed changes is that of making science more interesting and less frightening. But the results will be the opposite. Education has long been distorted by schemes that are supposed to make ideas simpler. No doubt it is possible to create initial interest and give temporary confidence in this way, but it does not last. Sooner or later pupils discover that they do not understand science, and often that their teachers do not also. Thus pupils become discouraged. Showmanship is no good substitute for scholarship.

The intellectual environment

We are trapped in a vicious spiral in which misinformed and confused teachers are required to present topics that they themselves have never had the opportunity to learn properly. They are given an overloaded, excessively advanced and ever-changing syllabus to teach. Books and other sources are often very inaccurate. Examiners are often ignorant and sometimes irresponsible. Official bodies, including the DfES, reject scientific criticism of the syllabus and examinations. Inspectors do not appear to notice. The present proposals will worsen, not improve, the situation.

J W Warren

Charging the Earth

Our recent article on 'Earth Science contexts for teaching physics' (King C and Kennett P 2002 *Phys. Educ.* **37** (6) 478–84) contained the following sentences in the section on 'Thunder and lightning' (page 483):

"A large positive charge builds up in the upper layers of a cloud and a large negative charge forms in the lower cloud. Since the cloud base is negatively charged, there is attraction towards the normally positive Earth, and the first stage of the flash brings negative charge down towards the ground. The return stroke is a positive discharge from the ground to the cloud that is seen as lightning."

This is correct, in that the Earth is normally positive under a thunderstorm, but is misleading in that it might be read as indicating that the whole Earth is normally positive. In fact, the Earth is normally negative and the fact that it usually becomes positive under an advancing thunderstorm can be used to predict that a thunderstorm is approaching.

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A problem in SHM

While John Roche's article on the introduction of SHM [1] is a commendable one, I want to draw the attention of readers to a difficulty, which I have noticed through informal discussions in the classroom.

The use of the adjective *restoring* for the force in the equation $F = -kx$ leads to the expectation of a driving force, because the bob moves away also from the mean position. This expectation of students becomes strong, especially after learning about the moving coil galvanometer, where the teacher refers to *the deflecting torque and restoring torque* acting on the coil. The idea of a driving force remains in the students' minds and this can cause problems in the comprehension of SHM, which have been observed by educationists through questions based on the simple pendulum.

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Reference

[1] Roche J 2002 *Phys. Educ.* **37** 497

All nations need to require science literacy courses for all university students

During 1994–2000, I attended six international or national physics education conferences in Europe and in China, most of them organized by international organizations such as the International Commission on Physics Education and the International Research Group on Physics Teaching (GIREP). The meetings, and especially the 'hallway conversations' with attendees, were delightful and interesting. I was pleased to have the opportunity to present invited and contributed talks at these meetings.

My reason for attending these meetings, and the focus of my talks, was the teaching of general 'physics literacy' courses to non-scientists, especially at the university level. It is an important goal for many reasons, most importantly because, as the American Association for the Advancement of Science puts it in its *Science for All Americans* project, 'The life-enhancing potential of science and technology cannot be realized unless the *public in general* comes to understand science, mathematics, and technology and to acquire scientific habits of mind; without a scientifically literate population, the outlook for a better world is not promising' (my italics). I believe that this statement is especially relevant to the *university-educated* portion of the 'public in general'.

My talks have always received a friendly hearing and general agreement at international meetings, but I have come to realize that these talks go out into an almost-perfect vacuum. With the important exception of China, no nations take any action to improve science literacy education: no new courses are developed, no new programs are started. Indeed, such possibilities are not even considered. I have discovered that the reason for this is quite simple: very few nations require students to take any courses in science literacy or in any other area outside of their major professional interest. University students of, say, music or history are not required to take physics literacy courses—courses that stress the conceptual (non-technical) understanding of the ideas of classical and modern physics, along with their social and philosophical implications.

Thus, the universities of most nations train professionals but they do not educate citizens. Evidence shows that this narrowly focused university education pattern is a mistake.

The work of Jon D Miller of Northwestern University (see references below) provides evidence that science literacy courses for non-science university students make a surprising difference in a nation's overall level of scientific literacy. Using carefully developed instruments, Miller builds on two decades of national surveys in the United States and two Eurobarometer studies to measure civic scientific literacy in several nations. In Miller's work, 'scientific literacy' means: (1) an understanding of basic scientific concepts such as the molecule, DNA, the structure of the solar system; and (2) an understanding of the nature and process of scientific inquiry, including the ability to separate scientific sense from pseudoscientific nonsense. In practical terms, scientific literacy reflects the level of skill required to read the science section of a major newspaper.

Miller found that the percentage of American adults who were scientifically literate increased from 10% to 17% during 1990 to 1999. Although these levels are low, surely too low for the requirements of a democratic society in today's world, they are higher than the level for European adults in 1992 (5%), for Canadian adults in 1989 (4%) and for Japanese adults in 1991 (3%) [7, p 2; 5, p 98].

In view of the weak showing of US secondary school students on such comparative exams as the Third International Math and Science Study, it is surprising that US adults are measurably more scientifically literate than European, Canadian or Japanese adults. At some point between secondary school and full adulthood, the average science literacy level of Americans seems to increase relative to other nations. Why?

Miller has studied the factors associated with scientific literacy in the US, evaluating the relative significance of the individual's age, gender, highest level of education, college science courses, minor children in the household and use of informal science education resources. He found that the strongest predictor of adult science literacy is college science courses, followed at a much lower significance level by informal science education, and then by highest level of education.

In his college science course indicator, Miller divided the number of courses into three levels: (1) no college-level science courses, (2) one to three courses and (3) four or more courses. Those individuals falling into level 2 took college science courses as a part of a general education requirement rather than as part of a major degree program. Thus, this indicator gives significant weight to science literacy courses, and the high significance of this indicator in predicting an individual's science literacy level is evidence for the importance of these courses in educating scientifically literate adults [7].

Miller comments that 'it is not well known in the scientific community that the United States is the only major nation in the world that requires general education courses for its university graduates. University graduates in Europe or Japan can earn a degree in the humanities or social sciences without taking any science course at the university level. ...Analysis of the data shows that this exposure to college-level science courses accounts for US performance.' [7, p 3]

All nations need to begin requiring science literacy courses for all university students.

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Publications by Jon D Miller

[1] *Public Perceptions of Science and Technology: A Comparative Study of the European Union, the United States, Japan, and Canada* (Madrid: BBV Foundation, 1997), with R Pardo and F Niwa

[2] *The Public Understanding of Science and Technology in the United States* A Report to the National Science Foundation (Chicago: Chicago Academy of Sciences, 1995)

[3] Civic scientific literacy in the United States: a developmental analysis from middle-school through adulthood *Scientific Literacy* ed W Gräber and C Bolte (Kiel: Institute for Science Education, University of Kiel, 1997) pp 121–42

[4] La nécessité d'une éducation scientifique citoyenne? *La Révolution de la Muséologie des Sciences* ed B Schiele and E H Koster (Lyon: Presses Universitaires de Lyon, 1999) pp 293–328

[5] Civic scientific literacy and attitude to science and technology *Between Understanding and Trust: The Public, Science, and Technology* ed M Dierkes and C von Grote (Amsterdam: Harwood Academic, 1999) pp 81–129, with R Pardo

[6] The measurement of civic scientific literacy *Public Understand. Sci.* July 1998, **7** 203–23

[7] Civic scientific literacy: a necessity in the 21st century *Federation of American Scientists Public Interest Report* January 2002, pp 1–4

'Ah-ha' moments

Bob Kibble's question 'Does the letter box really help?' in the last issue (*Phys. Educ.* **38** 59–61) provides a wonderful example of the way language can change its meaning. For him an 'Ah-ha' moment is a 'quantum step forward'. A quantum step is literally the smallest possible change made at random—so there could be a mixed message when using everyday language in a physics context!

My 'Ah-ha' moment with the metal grid polarizer was when asked why it didn't seem to act like a diffraction grating for the microwaves. After all, it looks just like a large diffraction grating doesn't it?

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