

LETTERS

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

A short note on the resonance tube

In some texts the phenomenon of resonance is often described by superimposing a transverse standing wave within the tube. This is done either (a) to draw an equivalence with the transverse wave pattern or (b) to *graphically* illustrate the respective displacement and pressure variations within the tube (figure 1).

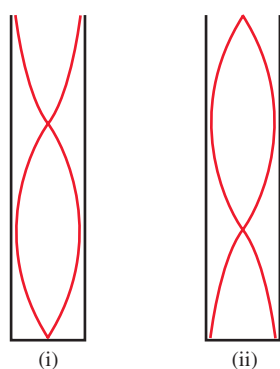


Figure 1. Graphical illustrations for resonance at three quarters of a wavelength.

Case (a) is conceptually confusing. Particle motion in a transverse wave is at right angles to the direction of motion of the wave. Particle motion in a longitudinal wave is in the same direction as the motion of the wave. The only 'equivalence' is in the shape of the diagram.

Case (b) must be explained very carefully to distinguish between the actual or true motion of the particles and the graphical plots. Again, drawing the plots inside the tube can lead to the same confusion as case (a), especially as this topic usually follows transverse standing waves on a string.

Although the graphical plots generally appear in advanced texts they should be drawn and explained separately if they are to be used. For by plotting the displacement of the

particle against the length of the tube inside the tube, one arrives at a transverse standing wave shape, whereas the actual motion of the particles is longitudinal.

Some elementary texts do not introduce the plots but only describe the actual motion of the particles. This seems the clearest approach. The total phenomenon can then be understood in terms of the individual particle behaviour (figure 2).

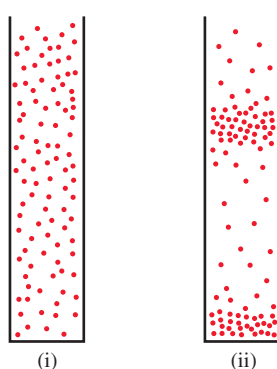


Figure 2. Individual particle positioning for (i) no vibration, (ii) at three quarters of a wavelength.

The individual particle motion and displacement are determined by the vibrations of the source, i.e. the longitudinal displacement varies from zero at the nodes to maximum displacement at the antinodes along the tube length. The pressure variations then follow intuitively, i.e. compressions and rarefactions respectively. The pressure plot is qualitatively useful; the 'displacement' plot may be dispensed with altogether.

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Ecological footprints

In my article 'A citizenship dimension to physics education'

(*Phys. Educ.* **37** (2002) 191), I compared the concepts of 'mass balance' and 'ecological footprint', mistakenly saying the latter is qualitative. I have since discovered (Edward O Wilson 2002 *The Future of Life*) that 'ecological footprint' too is defined quantitatively: it is the average amount of productive land and shallow sea appropriated per person, for food, water, housing, energy, transportation, commerce and waste absorption. Clearly such figures must be estimated. In the least developed countries the ecological footprint amounts to about 1 hectare (2.5 acres). For the world population as a whole it is 2.1 hectares (5.2 acres) and for the USA it is 9.6 hectares (24 acres).

Why do people everywhere want to emulate American standards of living? If every person alive in the world today consumed at an American level, we would need four more planet Earths to supply human needs and wants. If you want to prompt a lively discussion about sustainability, ask your students to do this dramatic calculation for themselves. Wilson goes on, 'A recent study of the concept of ecological footprint estimated that the human population exceeded Earth's sustainable capacity around the year 1978.'

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Forces and the little bang

I read Christina Hart's article, 'If the sun burns you, is that a force? Some definitional prerequisites for understanding Newton's laws' (*Phys. Educ.* **37** (2002) 234–8) with much interest, for I have often encountered pupils who have difficulty in understanding forces and allied matters. Her clearly presented consideration of an

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'agent' and 'receiver' of a force is an excellent way of treating the subject, but this does not go far enough. The article's omission is especially relevant since her choice of title refers to the sun burning human skin.

It is important to involve some concept of energy, however simple, while introducing the concept of force. The box headed 'Definition of a force' lists what may happen to an object that experiences a force. The first effect noted is a change in shape. Other kinetic effects are also given. But some pupils certainly suggest that a force can cause emission of sound. (It is possible that other pupils could even mention that a force can result in a temperature change, etc.) Hence, because at least the resulting sound is a well known consequence of a force's action, in an initial introduction to force there should be a reference to forms of energy and, depending on the pupils' level of understanding, a force's relation to these forms. For if this is brought up (as has been done often by my pupils), it becomes difficult to explain and understand unless energy is considered. So from my own experience the early introduction of such an association is essential.

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Teaching quantum physics

The 'electronium' model [1] for teaching the quantum atom is certainly an improvement over the misconception-prone Bohr model. However, it teaches that the psi-field (psi-function) is 'a substantial fluid or stuff', a notion that is itself an important and common misconception that will be hard to dislodge once it is taught in school classes.

It would be better to avoid quantum ideas and stick with a

qualitative non-quantized planetary atom until perhaps the 12th or 13th school year, when all students—scientists and non-scientists—should be sufficiently sophisticated to appreciate the *field* concept. I suggest that there might then be pedagogical and scientific merit in teaching quantum physics in the physically correct way, as a quantized field theory. All that is needed is quantum field theory's two most simple and fundamental concepts: First, the universe is made only of spread-out fields such as the electromagnetic field and the 'electron psi-field'. As Steven Weinberg puts it, 'The essential reality is a set of fields' [2]. Second, interactions are always quantized, i.e. they come in discrete bundles called 'quanta'.

The quantum field model of the universe is similar to the electronium model, but instead of a substance we now have a physically real field, the psi-field for an electron, photon or any other fundamental particle. For the case of an electron within an atom, the usual atomic 'cloud' diagrams picture the square of this field. It is spread out continuously around the nucleus. But whenever we detect (interact with) this field, we always get mc^2 joules of energy where m is the electron mass, i.e. we get a whole electron, because the psi-field is quantized in lumps of this magnitude. Psi squared represents the probability distribution of where the electron-detector interaction will occur.

A similar description applies to the electron double-slit experiment: the psi-field comes through both slits, i.e. 'the electron' comes through both slits. But since psi-fields are quantized, the interaction with the detection screen must occur in whole-electron units.

These two ideas are difficult, but there are only two of them and

one of them, namely fields, should already be known long before students tackle quantum physics. Students should understand, from classical electromagnetism, that electromagnetic fields fill all space, that they are not made of particles, i.e. they are non-material, that they nevertheless have energy, and that this implies the physical reality of these fields. A field is by no means simply an abstract mathematical quantity. Fields are what everything is made of!

Once students understand the classical electromagnetic field concept, their first quantum concept should be the quantized electromagnetic field, facilitated by examples such as the photoelectric effect and half-reflecting glass where each photon is detected on one side or the other with a 50–50 chance. Then students are ready to learn that the object they have always called 'an electron' is precisely analogous to 'a photon': electrons are quantized bundles of field energy, only in this case the field is of a new type called the 'electron psi-field' instead of the 'electromagnetic field'. The electron double-slit experiment is an excellent example to facilitate this learning. Then, and not earlier, students are ready to understand the quantum atom.

References

- [1] Budde M, Niedderer H, Scott P and Leach J 2002 'Electronium': a quantum atomic teaching model *Phys. Educ.* **37** 197–203
- [2] Quoted in Pagels H 1983 *The Cosmic Code: Quantum Physics as the Language of Nature* (Toronto: Bantam Books) p 239

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