# Letters to the Editor

## Leap seconds

Dr Essen's article "Leap seconds" in your July 1981 issue left unanswered what has been puzzling me ever since I built my "Rugby controlled" clock a few years ago. From my observations it appears the "atomic time" has to be corrected by adding the leap second at fairly regular intervals of just over a year. Fixed intervals mean a calibration error, i.e. the definition of the "atomic time" could be improved upon. At a rough estimate 9,192,632,000 cycles, instead of 9,192,631,770, would result in a better agreement, i.e. the leap second would have to be added less frequently.

If the sidereal clock deviated randomly from an imaginary "ideal clock" the best definition of the "atomic time" would be such that would result in the leap second having to be added with random sign at random intervals. I realize the sidereal clock, apart from random variations, also slows down as the Earth's rotation slows down. But this makes things worse: the atomic clock is already too fast.

Why has the apparently not-quite-correct definition been adopted? Perhaps sufficiently accurate data were not available at the time. But Dr Essen quotes an uncertainty of ±20 cycles, while one second in a year corresponds to approximately 290 cycles in $9.192 \ldots \times 10^9$.

Andrew Romer
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*The author replies:*

Mr Romer's comments on my article indicate that several points were not fully appreciated and deserve to be emphasised. The first is that leap seconds are not corrections to atomic time. The atomic second is the legal unit of time and is therefore constant by definition, as are the other fundamental units of measurement. Before it was adopted it was made equal to the existing astronomical unit in order to preserve the continuity of measurement, but is now used with its full accuracy and without any further reference to, or dependence on, astronomical measurements.

A scale of time could most logically be constructed by counting the number of seconds on a decade scale, a time interval being the number of seconds between two events; but it is a great convenience to use the atomic time scale, which is continuously transmitted, to give the time of day as well. The seconds are therefore counted using the traditional scales of 60 × 60 × 24 giving units of minutes, hours and days and designating these intervals by distinguishing marks. The scale was set so that it gave correct astronomical time on January 1, 1958. The time of day, determined of course from astronomical measurements, gradually diverges from atomic time as the rate of rotation of the Earth varies. When the divergence exceeds 0.5s the marker is moved along by 1s so that the signals give the time of day directly with an error not exceeding about 0.7s. These leap seconds must be removed for the measurement of true time interval.

Mr Romer also notes that leap seconds have, so far, all been in one direction. The explanation of this is that the atomic second was made as nearly as possible equal to the second of ephemeris time which was believed to represent the average value of the sidereal second over more than 200 years. If the rate of rotation of the Earth varies in the future as it has done in the past, then, in the long run, leap seconds should be required equally in the two directions although they would be expected to be in the same direction for a number of years.

In retrospect it might have been more convenient if a different value had been chosen for the unit; but some leap seconds would have been required in any case. The value chosen is not of much importance. The important thing is that we now have an extremely convenient, precise and constant unit in which to measure frequencies and intervals of time including the periodicities of the bodies of the solar system.

L. Essen

## Radio Amateurs' Examination

Criticisms of the Radio Amateurs Examination which have appeared in recent issues of your journal may have caused concern to the many thousands of individuals who annually seek this qualification, and I shall be grateful if I might be allowed space to answer, in some detail, the points which your correspondents have raised.

The examination, according to Mr Pat Hawker in your May 1981 issue (page 54) is "a lottery conducted in secret". Nothing could be further from the truth. The papers are compiled, by a group of subject experts with extensive knowledge of the theory and practice of the subject and similar extensive experience in teaching courses leading to the examination, from banked items which have been written by highly competent subject experts.

The papers are compiled in accordance with the examination specification published by the Institute in the syllabus pamphlet, 765 – Radio Amateurs Examination, and with the set of sample items from the question bank. Both of these may be purchased from the Institute's Sales Section by anyone wishing to establish the facts. Furthermore, permission to include the specification and sample items in textbooks is freely granted to authors and publishers, as well as to the correspondence colleges who prepare so many of the students for examination.

All the items appearing in the RAE question papers have previously appeared in public because they are pretested on a sample of at least 300 candidates as part of the item validation process. These pretests take place shortly before the date of the May examination, and when pretest papers are despatched to centres the course tutors are specifically asked for comments: a special form for these is enclosed in order to encourage a response.

Mr Hawker also suggested that the marking may be 'suspect' – a most serious charge which I refute absolutely. The candidates' answer sheets are optically scanned and, before the scores are output to the results determination part of the computer system, a preliminary item analysis is produced. This allows the statistics for each item to be checked. Any items which have been commented upon by examination centres are given special scrutiny and if a suspect item is discovered it is possible to instruct the computer to ignore it, thus effectively deleting it from the question paper.

This procedure was in fact activated in respect of two items in the December 1980 second paper, which had been made nonsensical as a result of printing errors. Whilst I accept that it is inexcusable for an examining body to have allowed such errors to slip through the checking procedures, nonetheless the question invalidation facility that I have described above, which was written into the multiple choice marking system for just such an eventuality, prevented any distortion of the results.

The other specific criticism of a question related to the following: "A standing wave meter is used to check the (a) stability of the oscillator (b) efficiency of the transmitter (c) resonant frequency of the aerial (d) operation of the aerial feeder." A subsequent check with members of the examination team indicated that recent technical developments might have made this item suspect.

In general, if an item is technically incorrect it becomes totally unacceptable. However, it is occasionally permissible, when framing items at a fairly low technical level, to make simplifications which, to the expert, would be unjustifiable. The statistics for this item gave no indication that the question was confusing to candidates:

| | Facility Value = 48.7 | | Discrimination Index = .470 | |
|---|---|---|---|---|
| | No. | (%) | LG% | UG% |
| A | 99 | (4) | 8.7 | 0 |
| B | 327 | (12) | 18.3 | 4.9 |
| C | 986 | (36) | 52.6 | 16.3 |
| D | 1350 | (49) | 19.2 | 78.6 |

(The correct answer is D).

Note: UG and LG stand for upper group and lower group, corresponding to the top and bottom 27% of the candidates on the paper as a whole. The analysis indicates the response preferences of each of these groups in percentage terms.

This analysis clearly shows that the students who got this question right belonged mainly to the upper group, i.e. those who tended to get a high score on the paper, which would indicate a better knowledge of the Radio Amateurs syllabus.

The other major criticism which I should like to refute for the benefit of your readers is the suggestion by Mr Osborne in your August 1981 issue (page 34) that "there are doubts about the validity of the examination". Doubts there may be in Mr Osborne's mind but they are unjustified. The Radio Amateurs Examination is a high quality examination of proven reliability which is designed, constructed and validated in accordance with the principles of modern achievement testing. The two basic criteria used to judge the quality of any system of educational measurement are *accuracy* and *validity*.

The RAE is *valid* if it measures an appropriately balanced selection of the objectives of the scheme. This balance is determined by a panel of subject experts devising a precise test plan which determines the proportion of the test related to each objective. Having an explicit plan means that the content balance of the tests can be kept constant from one examination series to another.

The *accuracy* of the RAE is checked by estimating the reliability coefficient for the test, i.e. an index of the proportion of the variation in