visor.

We ask our technical colleagues to propose job assignments, giving us information about the nature of the job, the supervision they will provide, and the background the student will need. Our judgment of these proposals is tempered by our knowledge that some supervisors have records of providing excellent summers for our students. We choose the assignments and match students to them individually. Some assignments have been: working as an accelerator operator; taking data on an experiment; analyzing data; building and testing equipment used in accelerator or experimental improvements, and working on the design of test equipment for superconducting magnets.

The students are here for 11 weeks in June, July and August. The Laboratory brings them by air and arranges housing at a nearby college. After considerable trial and error, we believe that the best and most economical way for the students to get between the college and Fermilab is to provide a leased car for every four students. They manage the sharing very well by themselves. We try to treat our students as professionals working physicists' hours, and transportation is a crucial part of the flexibility needed.

The Laboratory provides a stipend for the students at a level of approximately \$700 per month, not very different from what similar programs at other institutions provide. The Laboratory also subsidizes the students' housing. The participants in our program depend on summer earnings to help with college expenses. In most cases, they could probably save more money by working and living at home, but we try to give them educational benefits they could not get elsewhere.

As an adjunct to their work in their groups, we give a series of lectures on physics topics. At the end of the summer, each student gives a seminar on his summer work. He also writes a report on his work and an evaluation of the program. The reports are valuable training, and the evaluations help us to guide the direction of the program.

The lectures, seminars and oversight of the students' progress are managed and supervised by a coordinator who comes for the summer and spends full time on the program. He is able to correct difficulties that students are having with assignments or living arrangements. This close coordination and supervision has been an important part of our success.

Of the students who have participated in our program, approximately 40% are in graduate school, 25% are still undergraduates, 25% are active in scientific, engineering or technical careers, and 10% have moved on to other careers. We believe that we have influenced many young people toward careers in science, and we are proud of our record. We believe that our success comes from hard work in the ways outlined above. It is not a large program, but it is one of many small actions that will move us closer to the American goal of equal opportunity for all.

More information is available on our program and we plan to publish a more detailed account shortly.

Reference

1. A. Wilburn, Science **184**, 1148 (1974).

J. C. Davenport
Fermi National Accelerator Laboratory and Virginia State College
Petersburg, Va.
R. A. Carrigan, Jr
F. T. Cole
E. Malamud
Fermi National Accelerator Laboratory
11/11/76 *Batavia, Ill.*

Temperature scales

The beautiful work of Leslie Guildner at the NBS in gas thermometry (November, page 19), and the note that these better measurements of the thermodynamic temperatures of certain phase equilibria will be used in a new version of the International Practical Temperature Scale, raises questions on the making and changing of practical scales.

The Thermodynamic Kelvin Temperature Scale (TKTS) has a basis in nature. The International Practical Temperature Scales (IPTS) are artifacts and conveniences that exist by agreement rather than truth, and may be changed at will or whim.

But there is good reason not to change. A primary characteristic of a consensus measure must be stability, so that a measurement made at time t_2 can be compared with one made at time t_1 on the same scale, or so that an instrument calibrated at time t_2 will not have a different calibration than it had at time t_1 for reasons external to itself. History is less useful if it requires translation.

IPTS_{48} (with the *de facto*, if not *de jure*, replacement of the 0°C icebath with the much more precise 0.01°C triple point) was an entirely workable scale down to 90 K, and had the advantage of interpolation equations which could be done on a desk calculator. It is still the scale used in the bulk of US industry, for the economic burden of recalibrating US industry and of translating years of US product history for no particularly good reason is unthinkable.

IPTS_{1968} was constructed to bring the defining fixed points into closer conformity with what were the then best values for the TKTS. The cost of the change was mathematically horrendous interpolation formulas. Even then it was

KILOJOULES at 10.6 μ

If you are thinking of a high energy CO_2 Laser System, consider the following points – and a

LUMONICS TEA-620 LASER

Lumonics uv preionized TEA modules offer you:

CUSTOM PERFORMANCE FROM STANDARD MODULES

The Lumonics Modular approach allows assembly of oscillator, amplifier or combined systems of various sizes without extensive custom design.

FREEDOM FROM OPTICS DAMAGE PROBLEMS

Beam diameters up to 20 cm. reduce energy density on cavity optics.

MORE ENERGY PER EQUIPMENT DOLLAR

Along with low floor and console space, lower maintenance costs, less down time, etc.

GUARANTEED OPTICAL PERFORMANCE

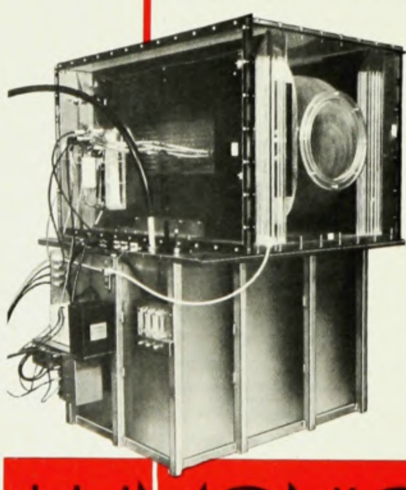
Lumonics provides the whole laser system including cavity optics. Pulse energy, peak power, time jitter and beam divergence are guaranteed.

HIGHER PULSE REPETITION RATES

More shots per dollar.

DESIGN SIMPLICITY

No vacuum systems, thin foils, water cooling or even 3 phase power is necessary. No countdowns needed to get a pulse out. Reliability is greatly enhanced.



OSCILLATOR ENERGIES TO 2KJ

DIVERGENCE TO .15 mrad full angle.

AMPLIFIER GAINS— > .04 cm^{-1}.

OSCILLATOR PULSE WIDTH — 40 ns — 60 us.

REPETITION RATE TO 1 Hz

L.75.1

LUMONICS RESEARCH LIMITED

P.O. Box 1800, Kanata, Ontario, Canada • K0A 2C0 • Tel. (613) 592-1460

Circle No. 12 on Reader Service Card

recognized that more sophisticated gas thermometry would yield new thermodynamic values, but the suggestion alternate to change, that IPTS$_{48}$ be retained and that values of difference from the TKTS be published periodically as better values emerged, was not accepted.

Guildner's exquisite technique says that this was a mistake. They show that where IPTS$_{68}$ did not change a value, that value is wrong, and that where values were changed, the value on IPTS$_{48}$ was closer to thermodynamic truth (see table below).

Fixed point temperatures

	IPTS$_{48}$	IPTS$_{68}$	Guildner, TKTS
Steam	100°C	100°C	99.975°C
Tin	231.913	231.9681	231.924
Zinc	419.505	419.58	419.514

Before we charge off again into change for the sake of a valueless correspondence, let's reconsider the virtues of a mathematically simple and elegant scale, a *practical* practical temperature scale, as one of my colleagues puts it, such as IPTS$_{48}$ was; and standing beside it, and modified from time to time as better values emerge from experiment, a table of difference between it and the TKTS.

HENRY E. SOSTMAN
Yellow Springs Instrument Co.
12/28/76 *Yellow Springs, Ohio*

Axons and axioms

In the October issue (pages 33–39) Gerald Ehrenstein gave a lucid and readable description of the present status of the observational knowledge of the ion channels in nerve membranes. Besides providing information the paper could make one curious to learn how much of this information can be related to axiomatic physics. I use the term "axiomatic" here in the sense that Tisza uses it; not to describe a system formalized to satisfy the standards of logicians, but physics in a form that clearly distinguishes input and output, the axioms and the derived concepts, and that spells out any tacit assumptions.

There was a large input to this subject of physics at an axiomatic level at the end of the 19th century and the beginning of the 20th century. This work was done particularly by Nernst, Planck and Henderson on analyses of the liquid junction potential, and by Bernstein who hypothesized the voltage variable membrane potential and carried out some virtuoso experimental studies. The observational aspects of the problem of the nerve action potential dominated the interest of biologists in the following decades. The input from physics came in the form of improved technology to carry out these observations. It might be said that this work was finally focussed in the work of Hodgkin, Huxley and Katz. Their observations made quantitative the empirical understanding of the action potential in the nerve axon, and in particular in the giant axon of the squid. These experimental findings Hodgkin and Huxley remapped into mathematical expressions for the transient sodium and potassium ion currents that are observed when the nerve transmembrane potential is varied in a step-function manner. This remapping was made in terms of mathematical variables, $n, m, h, \alpha_n, \beta_n, \alpha_m, \beta_m, \alpha_h, \beta_h$. Only one of the equations has a physical basis, this one being the equation of conservation of membrane current. The other three equations are only mathematical constructs that are designed to fit the data. These equations provide a reasonable description of the experimental results, and hence they form a satisfactory mathematical model for the action potential. But a satisfactory physical model was not forthcoming. In justice to biologists I must say that I have yet to find a biologist, or, for that matter a physicist familiar with the Hodgkin–Huxley equations, who does not protest that they and Hodgkin and Huxley are well aware that the Hodgkin–Huxley equations have no physical meaning.

Because the dominating interest of neurophysiologists since Hodgkin–Huxley has been focussed on gaining an understanding of the central nervous system, the development of a physical model for the action potential is a low-priority concern for biologists. The nerve action potential thus provides a fascinating opportunity for ingenious physicists to ply their trade without much competition, albeit probably without financial support for their research or audiences in either the world of biologists or physicists.

Some of the typical questions that remain to be answered are as follows:

1. If the stationary states of the permeability "system" vary with applied electric field, then the system free energy must vary with electric field. Hence a polarization of the "system" that is the canonical conjugate of the electric field exists.
2. A "system" consisting of a molecule with tens of thousands of atoms must have a very large number of configurational eigen-states available to it, instead of only the two or three that biologists assume. An observable of the "system" must be determined by the Gibbsian distribution functions as a statistical average over all the available states.
3. The description of the time dependence of the observables of the "system" must be given by the appropriate solutions of the master equation of the system,