

fine  $\mathcal{R}_i$  by the following expression:

$$|\mathcal{R}_i|^2 \equiv (\partial R_i / \partial X_j) x_j \dots x_{c+2}$$

where  $(R_i, X_i)$  is a conjugate pair of thermodynamics variables such as  $(-P, V)$  or  $(T, S)$ . Weinhold's papers<sup>1,2,3</sup> make it amply evident that this is an important alternative way of expressing the content of classical thermodynamics, providing very illuminating ways to view well known relationships and often providing generalizations that would be much more awkward in the conventional formalism. His approach is in the general spirit of recent important work by H. B. Callen<sup>4</sup> to show that the conceptual basis of thermodynamics is the restrictions on the behavior of the matter that follow from the symmetries of the fundamental laws of physics.

I would like to point out some related geometrical relations, which although not nearly so sweeping in scope or utility as those of Weinhold and of Callen are nevertheless rather interesting and readily accessible to anyone who has a grasp of elementary analytical geometry.

The first law of thermodynamics, in the form  $\Delta U = Q + W'$ , where  $U$  is the internal energy,  $Q$  the heat added, and  $W'$  the work done on the system, can be seen to conform to the definition of an ellipse as the locus of points such that the sum of the distances from the two foci is constant. A given internal energy corresponds to an infinite family of ellipses but a specific system and/or process would correspond to an ellipse with a given eccentricity and spacing of foci. If the usual convention of treating work done by a system as positive ( $W = -W'$ ) is used, then the First Law can be represented as a hyperbola.

A different and somewhat more interesting approach, which also introduces some new angle variables, is to consider the First Law as

$$Q = \Delta U + W \text{ (general process)}$$

$$\int TdS = \Delta U + W_r \text{ (reversible process)}$$

and the second law as  $W_r \geq W$ , or  $Q \leq \int TdS$ . Now imagine a set of generalized coordinates such that velocities squared are proportional to energies, or such that velocities are the square roots of energies with the proper choice of the "mass." Thus  $(\Delta U)^{1/2}$  acquires the interpretation of a velocity or a momentum, as do  $Q^{1/2}$  and  $W^{1/2}$ . With this interpretation, the first law is seen as a relation between the squares of vectors, and in fact, as the condition for a right triangle with sides  $(\Delta U)^{1/2}$  and  $W^{1/2}$ , and hypotenuse  $Q^{1/2}$ . The figure shows the triangle for the first law and neatly reduces the second law to the statement that the triangle for a general process must lie within or on the one

for a reversible process, or that the angle  $\alpha_r$  between  $(\Delta U)^{1/2}$  and  $(\int TdS)^{1/2}$  for the reversible case must equal or exceed  $\alpha$  for the general case. For a specified system and process, the irreversibility is characterized by the angle  $\Delta\alpha = \alpha_r - \alpha$ . The law of cosines applied to the upper triangle provides an interesting new relation

$$\frac{1}{2} (W_r + W) - (W_r W)^{1/2} = \frac{1}{2} \left( Q + \int TdS \right) - \left( Q \int TdS \right)^{1/2} \cos \Delta\alpha$$

which implies that the arithmetic mean of the absorbed heats exceeds their geometric mean by a larger amount than the arithmetic mean of output works exceeds their geometric mean. When either  $U$ ,  $Q$ , or  $W$  is negative, the interpretations are not as simple.

## References

1. F. Weinhold, *PHYSICS TODAY*, March 1976, page 23.
2. F. Weinhold, *J. Chem. Phys.* **63**, 2479, 2484, 2488, 2496 (1975).
3. F. Weinhold, *J. Chem. Phys.* **65**, (1976) (to be published).
4. H. B. Callen, *Foundations of Phys.* **4**, 423 (1974).

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## UFO journal

In connection with the recent correspondence in your columns about the UFO observations, your readers should be informed of the formation of The Committee for the Scientific Investigation of Claims of Paranormal Phenomena, under the sponsorship of the American Humanist Association. This Committee will publish a biannual journal, *The Zetetic*, this Fall, at \$10.00 per year. The Managing Editor may be addressed at 923 Kensington Ave., Buffalo, N.Y. 14215.

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6/16/76

## Debunking astrology

I wish to comment briefly on your review of *Objections to Astrology* (March, page 54). Your reviewer, Robert H. March, asks: "To whom is this book addressed and what end does it serve?" As far as I am concerned, I made the effort of organizing the articles for the book for two primary purposes, which have been achieved. The first one was to warn young people against accepting astrological predictions without question. The second was to provide them with a clearly written statement showing that astrology totally lacks a scientific foundation.

From 1930 to 1974, I taught regularly at least one half of a beginning course in as-

tronomy, first at Harvard (1930-1956), later at the University of Arizona (1966-1974). During the past few years, I again became quite disturbed by the many requests from my students regarding the astronomical foundations for astrology (or lack of the same) that came my way. I would answer my students' questions, but I could not refer them to any published, up-to-date, concisely written answers to their inquiries. With the recent increase of interest in astrology, and the increase in astrological publications, young folks simply lack a firm statement about the astronomical evidence against astrology and they naturally turn to their astronomy teachers for advice and information. My article was specifically aimed at enlightening the young people who want this sort of information. There are old people who need this information as well, but I do not care as much myself how those folks think. However, it is most important that young people should realize that they must learn to use fully their God-given rights. They must learn to think out their own problems and make decisions wisely themselves, instead of becoming dependent on astrological predictions, as many are today. They must be "tubs that stand on their own bottoms."

As I see it, we have no hope of reforming the dyed-in-the-wool believers in astrology. For some, at least, astrology is almost like a religion, and all I can say is that they hold their beliefs on poor basic grounds. There are others who take advantage of astrology simply for financial personal gain. It does seem to me that I, as an astronomer, trained and supported in my work by public funds, have a duty to inform the general public and warn them that there is no foundation for astrology. I shall continue to do this as best I can, hopefully paralleling my activities with those of many of my scientific colleagues.

Some of my correspondents ask what harm is done by having people believe in astrology—it is all fun and games! Some of the letters I receive show the way in which real harm is being done. The daily columns on astrology in the newspapers (1300 of them) are not just fun. To take an example: One morning our otherwise excellent local morning paper in Tucson omitted the daily column on astrology. There were dozens of telephoned complaints. One came from a woman who was most upset for, because of the omission of the daily column on astrology, she did not know how to organize her day. She was apparently quite desperate about it all. I note that in several letters from astrologers the daily columns on astrology are shown to be of no value. And yet, vast amounts of money are earned by astrologers, and lots of papers are sold because of this admittedly fraudulent practice of serving this daily brew to gullible customers.