University of North Carolina student, in a class using my book, put it this way: "The book fits comfortably into the growing trend of linking science to the humanities. The basic criticism I forsee is that the book is a bit too trivial for first-year college students. The critics will perhaps believe the book to be of more benefit on the high-school level. I would not agree with the latter point."

In anticipation of Von Foerster's call for "padding" to make my text usable in a full-year course. I have prepared an accompanying collection of articles, including contributions by Arthur Koestler, John Maynard Keynes, Merle Tuve, Jean Piaget, *physics today* editor Harold Davis, I. I. Rabi, Roger Bannister, Robert Oppenheimer and Edward Teller, among others.

Robert Karplus
University of California
Berkeley

Fresnel and the tachyon

In connection with the recent wide interest in tachyons (May, 1970, page 13) readers of *physics today* might like to have their attention called to a case where it seems that tachyons are quite close at hand.

What one does with an imaginary proper mass, one does just as well with an imaginary component of the momentum. Fresnel's evanescent wave in total reflection is formally a plane wave with a complex propagation vector **k**, having (in units such that $c = 1$ and $\hbar = 1$, and ω denoting the angular frequency) components $k_x > \omega$, $k_y = i\,(k_x^2 - 1)^{1/2}$, $k_z = 0$. That *lichtquanta* associated with such a wave will behave, in some essential respects, like tachyons is easily demonstrated. It is well known that the imaginary part k_y of the phase contributes in fact to the amplitude of the wave. Of course the corresponding real exponential factor can be expanded as an ordinary Fourier integral; the point is however that conservation of the energy-momentum with ω and k_x fixed forbids any of these Fourier components to be separately absorbed or emitted; only the whole phase-coherent Fourier integral, that is, the imaginary quantum k_y, can be absorbed or emitted.

Then it is easily verified[1] that if, say, an ion beam is sent in the evanescent wave parallel to x with exactly the appropriate velocity, it will simultaneously absorb an energy quantum ω and a momentum quantum $k_x > \omega$ by going from one eigenstate to the other, and that the transition amplitude will be proportional to the product of the x, y, z expressions of the amplitude of the ionic wave and of the evanescent electromagnetic wave. An experiment is presently planned along these lines.

Finally we come to the question of the group velocity. It is well known that for deriving a group-velocity formula one needs a stationary phase argument *plus* another constraint. With tachyons proper, using de Broglie's constraint that the proper mass is dispersionless, one obtains a spacelike group four-velocity collinear with the four-momentum. With our tachyon photons we have dispersions $\delta\omega$ and δk_x, and we have to impose a correlation between them. Choosing $\delta[(n^2\alpha^2 - 1)^{1/2}\,\omega] = 0$ where, n denoting the index of the refracting medium and α the sine of the incidence angle inside it, $k_x = \eta\alpha\omega > \omega$, that is distributing our tachyon-photons with respect to their penetration depths, we obtain $\omega\delta\omega - k_x\delta k_x = 0$, which together with $\delta d\phi \equiv \delta\omega\, dt - \delta k_x\, dx = 0$ yields $dx/dt = k_x/\omega > 1$—a reasoning and conclusion quite similar[2] to those applicable to tachyons proper. But neither for tachyons proper (if they exist) nor for these tachyon-protons (that should exist) is there ground to believe that a signal velocity could be greater than one.

References

1. O. Costa de Beauregard, Compt. Rend. **270B**, 773 and 1004 (1970).
2. O. Costa de Beauregard, *Précis of Special Relativity*, Academic, N. Y. (1966), page 110. Equation 7 in this work should read $\beta_F \simeq -\eta/n\alpha\omega \simeq \beta_E$, that is, in the form of generalized Doppler effect.
3. Ch. Imbert, Compt. Rend. **269B**, 1227 (1969) and **270B**, 529 (1970); Phys. Lett. **31A**, 337 (1970).
4. F. Goos, H. Hanchen, Ann. Physik l, 133 (1947).

O. Costa de Beauregard
Institut Henri Poincaré
Paris

Still more on tachyons

O. M. Bilaniuk and E. C. Sudarshan have pointed out (May 1969, page 43) that it is very important to make sure that tachyons are consistent not only with relativity theory but also with quantum theory. I would like to comment on this point.

Bilaniuk and Sudarshan have studied the dependence of $E/|m_0|c^2$ versus $P_x/|m_0|c$ (their figure 1). For a given momentum P_x there are therefore always two values of the energy, $+E$ and $-E$. It is just this double sign for the energy that necessitates the use of a four-component wave function in Dirac's wave equation.

With the smallest value of $P_x = 0$ we associate two values of $E_0 = \pm m_0c^2$. The particle can not exist in the region $m_0c^2 > E > -m_0c^2$, because P_x must be

continued on page 63