

**M**ANY OF US, unfortunately, still think a liberal-arts student is a sort of dumb physics major, someone who just couldn't make it in science and mathematics. We therefore try to teach him physicist's physics, but in slow motion as befits his mental ability. And we insist on addressing him in our mathematical idiom although mathematics is for him a foreign language. The humanists, symmetrically, believe that anyone who chooses an "exact" science like physics or mathematics is likely to be an unimaginative and not very literate clod, whose grasp of things is confined to linear thinking.

The truth of course is that both bright and dull people can be found in both camps; it is only that they hear the sound of different drummers. We physicists want the other fellows to hear our drummer too, but we can hardly expect them to fall in step and march to the same beat. They must therefore be met on their own terms and in their own world. We might otherwise just as well crawl back into our shells and resume talking to each other, as we have always done in the past (except for occasional brief forays outside to capture some funds or see a play, perhaps).

#### *Disinterest becomes rejection*

In the effort to make physics a part of the educational background of non-scientists, we have long contended with boredom; recently something new has been added: rejection. What was once mere disinterest has somehow

been promoted to a cause. Not all the antiphysicists in the universe are composed of antiparticles; some exist in our own society. That golden age of physics, when it seemed as if we were destined always to skim the cream of the students, and society was willing to support physicists while they talked only to each other, appears to be over. It looks as if we may have to go out and sell the product, as does everybody else.

I am not suggesting that most of society, or even the liberal-arts students, are hostile to science and scientists; certainly only a small minority would admit that they are antiphysicists. But it is a mistake to assess the influence of a movement merely by counting the number of extremists in its ranks; extreme positions have a way of establishing frames of reference for everyone else. One has only to see the transformation that has taken place in art, music, theater and motion pictures to realize that even the squarest among us has not escaped entirely the cultural influence of the new nihilism, if only in its accompanying symbology of clothing and hair styles.

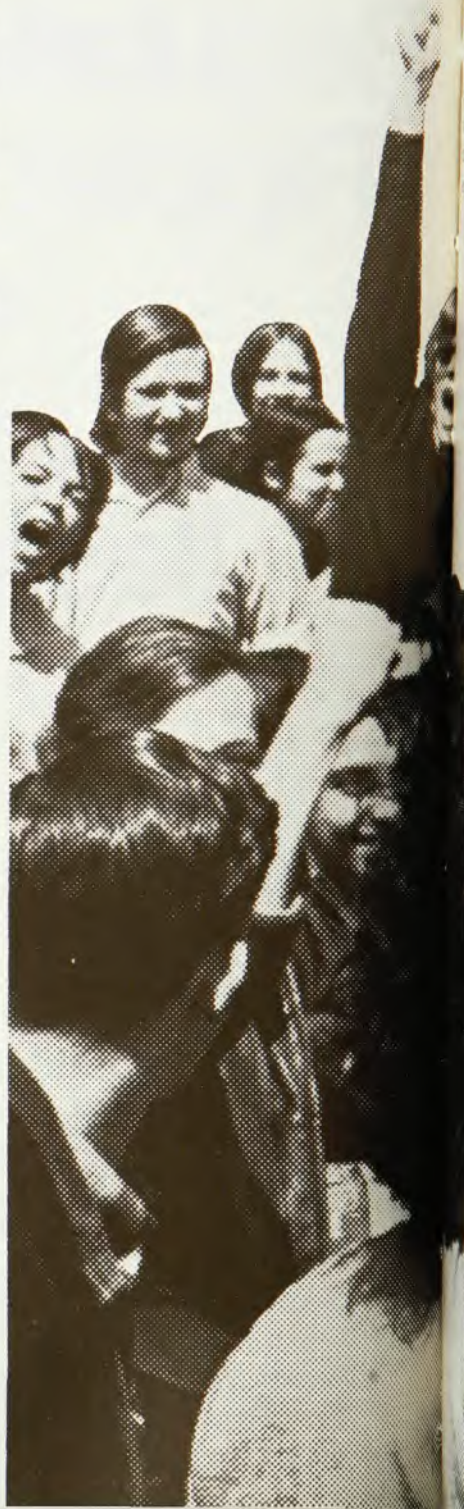
Our youth culture contains a very loose alliance of opposites, a strange combination of withdrawal from society on the one hand and violent political struggle on the other. I am not judging the ultimate significance of these trends, nor am I suggesting that political activism is synonymous with alienation. Constructive involvement of the young in political and social is-

ues is one of the most hopeful signs of the times. It may turn out that the responses of young people today are a good deal healthier than the society that produced them. But what is of concern to the scientific community, and what we must come to grips with, are those aspects of the new wave that distrust and reject the very processes of reasoning and rational discourse. This type of antiscience is in the air we breathe today; on the one hand in the unrestricted hedonism, the emotions conveyed by pop records and the drug

## THE NONSCIENCE MAJOR PHYSICS AND ANTIPHYSICS

Adolph Baker

How do we show those students  
who believe physics to be a force only for evil  
that physicists care  
about the real world's problems?



subculture, and on the other hand in the violent forms of political self-expression that refuse to consider causal relations and become an end in themselves.

Paul Goodman, educator and author of *Growing Up Absurd*<sup>1</sup> and other books, refers<sup>2</sup> to the antirational trend as a new religion on the upswing. "Dissident young people are saying that science is antilife, it is a Calvinist obsession, it has been a weapon of white Europe to subjugate colored races, and scientific technology has become manifestly diabolical." As an example he describes his experiences in a course on professionalism that he gave at the New School for Social Research in New York. The course was attended by graduate students from various departments, and this antirational outlook became evident. "As we explored further, we came to the

deeper truth, that they did not believe in the existence of real professions at all; professions were concepts of repressive society and 'linear thinking.' I asked them to envisage any social order they pleased, Mao's, Castro's, some anarchist utopia . . . and wouldn't there be engineers who knew about materials and stresses and strains? Wouldn't people get sick and need to be treated? Wouldn't there be problems of communications? No, they insisted; it was important only to be human, and all else would follow.

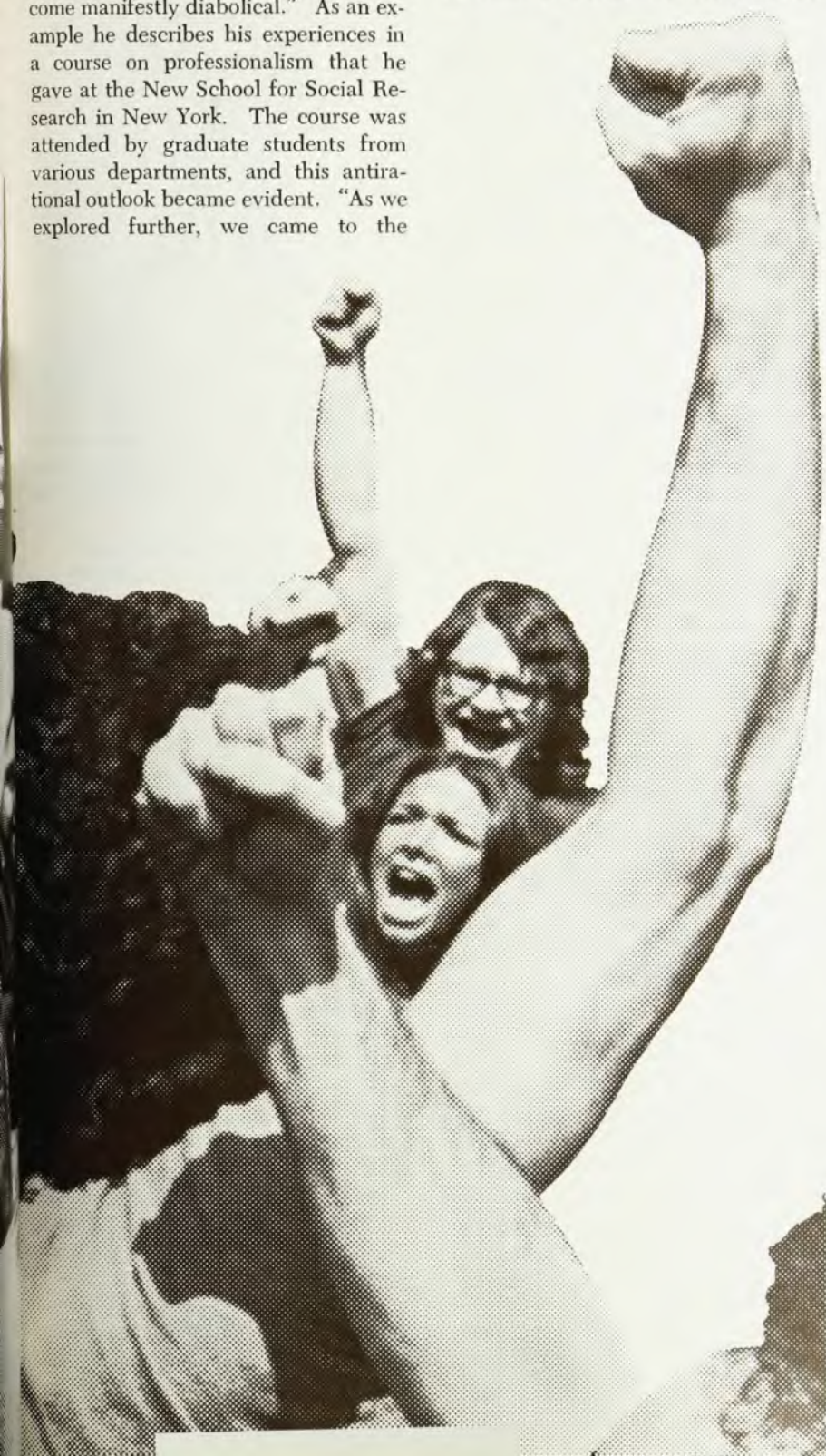
"Suddenly I realized that they did not really believe that there was a nature of things. Somehow all functions could be reduced to interpersonal relations and power. There was no knowledge, but only the sociology of knowledge. They had so well learned that physical and sociological research is subsidized and conducted for the benefit of the ruling class that they did not believe there was such a thing as simple truth."

Goodman concludes that "the worldwide youth disturbance may indicate a turning point in history, and we must listen to it carefully." He may, of course, be overreacting. Perhaps, as some of us contend, it is just the same old youthful rebellion, or a passing fad as was flagpole sitting or goldfish swallowing. But if, as many young people (and a number of not so young sociologists and anthropologists) maintain, the present problems of society are serious enough to endanger the survival of civilization, then we may be in for a long siege.

#### *Roles of the university*

What has all this to do with teaching physics to nonscientists? We should be under no illusion that it is within our power to reverse present trends on the educational level alone; the problems of young people are not abstractions that can be talked out of existence. But I do not believe that we can afford to conduct business as usual on the assumption that if we pay no attention it will all go away. The educational system is changing rapidly, and shortly things will not be what they once were. The universities have two responsibilities, and to some extent these are in conflict: One is to contribute active leadership during periods of political and emotional crisis; the other is to preserve islands of reason and objectivity and to keep as many people intellectually free as possible. I do not believe that these objectives are best served any longer by maintaining the traditional separation between physics and the rest of life. The humanities are in touch with the majority of young people, and academic humanists are in the vanguard of the new movement. Yet we continue for the most part to teach physics as if nothing has happened.

Some think the "purity" of science demands that it remain detached from social or political questions. There is much to be said for this custom, at least with respect to actual scientific



developments, although I can conceive of situations in which this restriction breaks down altogether. But in communicating with the public or in courses for nonscientists there is really no good reason for maintaining such a dichotomy. In particular, there is no law prescribing that science and the cultural effects of science must always be discussed in separate classrooms or separate books. I suspect that it is precisely such compartmentalization that makes physics a dull subject for humanists. The objectivity of science will most probably not suffer as a result of teaching physics and exploring its social implications in the same breath, and this truth is beginning to be recognized in a sprinkling of new experimental courses that have recently been developed.

I have tried to find a common ground with humanists in a book,<sup>3</sup> *Modern Physics and Antiphysics*, designed for people who are literate and have a fair measure of intellectual curiosity. It is not a formal textbook; hardly anyone ever *reads* a textbook. It could perhaps more properly be described as a view of modern physics in the context of our times, but with the physical principles explored in depth. The focus is on physics of this century; only as much classical physics is introduced as is needed to support the modern physics.

Controversial topics, instead of being avoided, are deliberately injected. Assorted characters break into the discussion with comments and questions. A dialogue between a Poet and a Scientist provides a sort of Greek

chorus throughout the book; this chorus anticipates the kinds of interruptions (not always about physics) that a reader might want to interject. Even the antiscientific viewpoint is given a hearing. The protagonists polarize into extreme positions (the Scientist is kept distinct from the author) and provide a form of conversational therapy—oases of unphysics after the more difficult physics developments. The argument begins even before the physics does:

**Poet:** You have not yet told me what physics is, except to suggest that it is not the study of dead things. Could it perhaps be a method for reducing everything to dead things?

**Scientist:** You're still blaming me for the atom bomb.

**P:** Not I. It's the voice of your conscience.

**S:** In the first place you are confusing science with technology. And in the second place there were very good reasons for what we did during the second world war. But in any case that is not what physics is about.

**P:** It seems to me you run with the hare and hunt with the hounds. All right. Tell me what physics is about.

**S:** The physicist looks for a structure which will enable him to make an orderly model of a chaotic universe. In principle it should eventually become possible to extend the methods of physics to all fields of knowledge, but in practice this still appears to be somewhat ambitious. For one thing there are difficulties with the mathematics in handling complex systems. For another some important links are still missing. But the objective is to achieve actual understanding, not just a collection of facts. To accomplish this physicists have to go wherever their travels take them. It is impossible to predict all the social implications of fundamental research. Columbus did not anticipate that he would discover a continent. He set out to test a theory, and to find a new path to the Orient. The important thing is that he went.

**P:** But we already see where your travels are taking us. Your beautiful plastic-and-steel civilization has poisoned the air, turned cities into ghettos, and made mass murder our major national product. Soon perhaps the world will be a silent sepulchre, and there will be no one to hear the clicking of Geiger counters.

**S:** I do not share your pessimism. And I am making an effort to keep my



temper. If we are to start placing blame, then tell me what contributions to our brave new civilization you have made lately. Even when nations are ruled by buffoons, the speeches are written by poets. Or is it perhaps the cigarette commercials you take pride in?

**P:** I do not write commercials.

**S:** And I do not make bombs."

### Generalizing symmetry

The actual physics discussion begins with symmetry relations; parity conservation is a convenient point of departure because it requires so little preparation and because the general symmetry argument may then be used in subsequent developments. An important initial objective is to erase, as quickly as possible, the prevailing image of physics as a branch of technology, a mere series of devices for solving problems in plumbing and transportation. The Poet listens and participates occasionally; then he bores in again:

**P:** It was an interesting discovery. But I wonder if the game is worth the candle. Physicists have learned that parity is not conserved in weak interactions, and astronauts have walked on the moon. Meanwhile the rest of the world is unsuccessfully coping with the problems of poverty and war.

**S:** Actually, symmetries are not the exclusive province of artists and scientists. The very process of juxtaposing



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and examining real or supposed differences between individuals, groups, parties, races, nations, is itself a search for symmetry or lack of symmetry. I believe one can learn from the experience of the physicists in handling their 'simple' problems. The symmetry property is a logical way of formulating a question. In the problems of our cities, for example, it is black-white symmetry; when we wonder about the role of women in society, it is male-female symmetry; in international politics it is east-west symmetry. Is it really true that Chinese are so different from Americans that they 'don't mind' losing half their population in a nuclear war? Does oriental psychology differ from occidental psychology? How would a black society in America 'enforce law and order' in cities filled with white rioters?

A physicist may not ask precisely the same questions a sociologist asks, or a politician, or an educator. But the scientific method suggests a style of reasoning which demands precise formulation of a problem, and exposes preconceived ideas to objective and

hostile scrutiny. This type of questioning is not conducive to the stability of a tyrannical government. A people which has been educated to scientific reasoning is, I believe, less inclined to accept rule by dogmas and slogans; nor is it easily persuaded to fight holy wars.

P: Then how do you explain Nazi Germany?

S: Technology flourished, but I would not call the Third Reich a scientific nation. It collected some of the dividends of past science. In order to fulfill Hitler's ambitions for the German people, it was necessary to destroy science while preserving technology. German science has to this day not fully recovered from the damage it sustained under Hitler.

P: I fail to see any consistent improvement in the human condition resulting from your type of analysis. It may even be precisely the other way around. Every time you make a discovery or take a step to advance your field, you like to think you are improving man's state. And all you do is strengthen the hand of an establishment which turns everything to its own advantage. It makes no difference how beautiful the experiment, or how elegant the style of reasoning, it always ends up as bombs and napalm.

S: Would a return to ignorance solve the problem?

P: No, but we could stand a change of emphasis. The planets and the elementary particles have been around a long time, and they can wait a little longer.

S: You mean the conquest of nature should be forced to come to a halt until men have solved all their social problems.

P: You are so preoccupied with the conquest of nature that you fail to realize that people are a part of what is being conquered. You are so busy spraying the insects with DDT that you can't take time out to notice that the birds have stopped singing.

S: What do you propose? Shall we join the flower children and look for 'expanded consciousness' through drugs while we await our extinction?

P: I wouldn't underestimate the hippies. They knew instinctively that the only way to avoid helping the establishment is to get outside it. As long as you try to function within it you end up becoming part of it. There is a place for everyone, even the dissenters. The idealistic white social worker enters the black ghetto to 'help' impoverished people, and the

establishment uses him to reduce unrest and keep the people from throwing rocks through its windows.

S: There is something very false about this argument of futility. Withdrawal from society is just another luxury of the affluence which is supposedly being renounced. In order to bemoan the loss of microbes which have so zealously guarded the balance of nature you have to be born in a world without smallpox and plague. In order to develop a contempt for material wealth it has to be all around you. You turn on your stereo system and lie back dreaming of the days of the noble savage. These people who affect the anti-status symbols, the fetishes of the studied unkempt look and the torn jeans,—do you believe their behavior actually conveys a message or represents a viable solution?

P: They are after all very young, and not always articulate. How else are they to tell you that they have rejected the values of your siren song of progress?"

### Scientific reasoning

Most of the book is physics rather than talk about physics, although these particular selections may not reflect this fact. Questions at the ends of chapters alternate between physics and nonphysics applications of the principles that have been introduced. Topics chosen for discussion, however, are those that can be made most meaningful to the humanist reader; they are not necessarily the ones that are most important and beautiful to a physicist (although there is a fairly large region of overlap).

The nature of our civilization is such that it becomes increasingly absurd for the bulk of our educated population to have not the slightest grasp of a scientific style of reasoning or the importance of observation and experiment. We should be conveying these ideas to students and not merely teaching them the facility for substituting in physical formulas. They never really come to believe or understand the formulas, and will undoubtedly soon forget them. Many of us still foster the illusion that we can force them to learn on our own terms. Even if this was ever possible, the permissive society that has been evolving under our noses for the past few decades now precludes any such consideration.

I have tried to interest the humanist reader not only in the findings of modern physics, but more especially in the

techniques and processes of analysis that produced these findings. I suggest at the outset that current intellectual freedoms are not unrelated to the breakdown of traditional concepts and fundamental structure, a breakdown that was initiated by the modern scientific revolution. The book then proceeds to explore the developments that led to relativity and quantum mechanics, and tries to show that the familiar psychological problems confronting the reader today are not so different from those problems that scientists originally had to face. It is also important for him to know that physicists are as concerned as he is about the dangers to our survival, that social consciousness commutes with rationality, and that although the problems of society are in part the product of scientific discoveries, they are not likely to be resolved by a rejection of reason and objectivity.

### Physics and human problems

Physical principles are expounded by consideration of the experimental evidence and the use of qualitative arguments. (An appendix develops the more rigorous mathematical details both for readers who are of a mind to pursue them and for lecturers.) But the physics itself is presented so as to change the prevailing image of science and scientists as detached from human problems. The following set of questions appearing at the end of a chapter

on space contraction and time dilation may convey the mood:

"As a result of consistent failure to agree on anything, there has been a deterioration of relations between the Platform People and the Rocket People. An arms race has begun, and each side is convinced that the others are out to destroy them in order to prevent them from destroying the others first. At 3:00 o'clock, when the Platform People are holding a Red Alert to test the effectiveness of their defenses, the Rocket passes them at a constant velocity equal to one-half the speed of light. As is the custom on such occasions, everyone synchronizes clocks. However, to the surprise of the Platform People, the Rocket People are also holding a Red Alert.

'It would be quite a coincidence,' say the Platform Strategists, 'for them to be holding their test Red Alert simultaneously with ours. What seems more likely is that they do not believe ours is only a test alert, and they have therefore started the real thing. If that is true, then according to our calculations they should be launching their first strike missiles in just one hour from now, at 4:00 o'clock. On the other hand, if it is only a routine alert, it will be all over by 3:30 and they will be returning the covers to their missile silos. We have instructed our surveillance outposts, whom the Rocket will be passing in half an hour, to keep us informed. If by 3:30 their

countdown is still proceeding, we will launch our antimissile missiles.'

'Hold on a minute,' says the Platform Observer. 'That is a pretty extreme measure. Suppose there is a miscalculation, and it is only a test alert after all.'

'We have considered that possibility too,' say the Platform Strategists. 'The safest thing to do in such cases is to proceed on the basis of their capabilities, not their intentions. The beautiful thing about our antimissile missiles is that they are programmed to attack only other missiles. Civilian populations and cities have absolutely nothing to fear. If they fail to encounter any enemy missiles, they will change course before penetrating the Rocket People's radar screen, and no harm will be done. Our system is absolutely fail safe and fool proof. Those antimissile missiles secure the credibility of our nuclear deterrent; they are our guarantee against an enemy miscalculation. Of course if the Rocket People have really started a war, we will have the jump on them. We will see the flashes when our antimissiles destroy their strategic missiles, and with their first strike capability wiped out, we can really clobber them.'

Unfortunately the Rocket People also have their Strategists, who read the same books as the Platform Strategists and have reached the same conclusions. They too suspect the Red Alert of the Platform People, and have



"WE INSIST ON ADDRESSING him in our mathematical idiom, despite the fact that this is for him a foreign language. . ."

embarked on precisely the same course of action.

1. Describe what happens at 3:30 in the Platform frame of reference.
2. Which of the following statements is most nearly correct?

- (a) The Platform People launch their missiles before the Rocket People.
- (b) The Rocket People launch their missiles before the Platform People.
- (c) Both sides launch their missiles simultaneously.
- (d) None of the above.

3. The Platform People and the Rocket People have completely destroyed each other's populations, except for one sole survivor on either side. These survivors are now arguing their respective cases before the Galactic Historian, in an effort to get the record straight. The subjects at issue are:

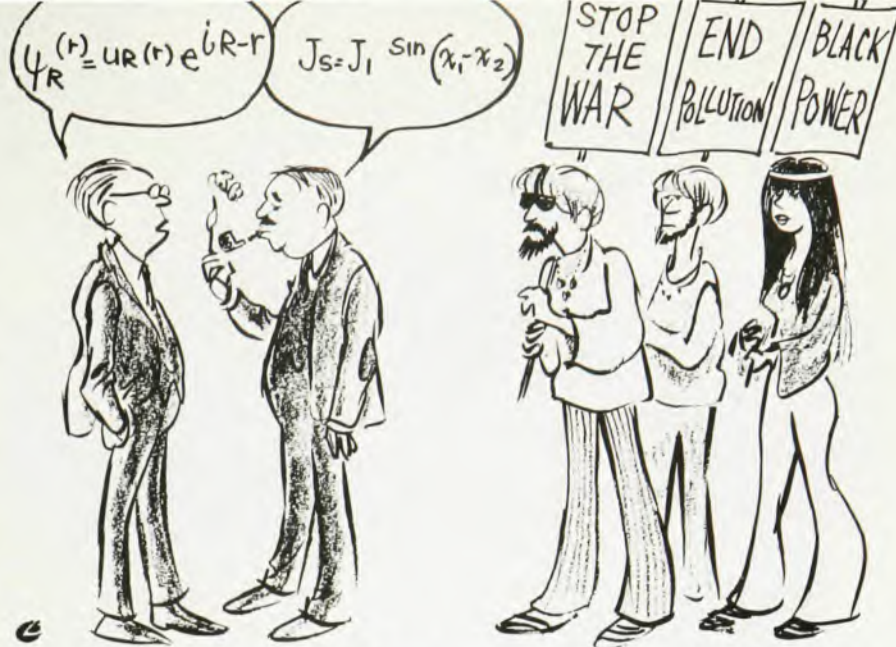
- (a) Who was the aggressor?
- (b) Who won the war?

The platform Survivor argues, 'Clearly we were not the aggressors, since the missiles we launched first were strictly defensive weapons, and if the Rocket People had been as peaceful as they claim, no harm would have been done. On the other hand, since we got the jump on them, we must have won the war, although I admit things got rather confusing for a while.'

Compute the time the Platform People launched their antimissiles, and the time the Rocket People launched theirs, all in the Platform frame of reference. (You will need to use the time dilation equation (8-2) for determining the time elapsed on a Rocket clock, since clocks were synchronized, as observed in the Platform frame of reference.)

4. Now compute the times of these two events in the Rocket frame of reference. Thus you should discover that it is possible for an event A to precede an event B in one frame, and yet have B precede A in the other. This may perhaps disturb you, by raising questions about the relationship between cause and effect.

5. Show, however, by considering the locations and times of these events in the Platform frame of reference, that once the missiles were launched by the Rocket People, information about this launching event (traveling even at maximum speed in the form of light or radio signals) could have reached the Platform People only after they had al-



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ready launched their missiles. This is an illustration of the fact that when two events occur in reversed order in different frames of reference, neither event can actually influence the other. Thus there is no violation of the principle of causality, which links cause and effect. Otherwise a father could be born before his son in one frame, and the son before the father in another frame. Fortunately relativity does not impose such awesome conclusions upon us; the father always precedes his son no matter what the frame of reference. It can be shown that two events which are connected by a causal relation (one being the cause and the other the effect) will occur in the same time order in all frames of reference, despite the existence of time dilation. But when events are so far apart in space, or so close together in time, that light sent from event A arrives at location B only after event B has already occurred (and vice versa), only then can the order of the events be reversed in another reference frame. In such a case A and B would have no influence on each other. This was the case with the two launchings. Both the Platform People and the Rocket People have only themselves to blame for what occurred, and the Galactic Historian will so record it."

The physics in these problems is undoubtedly a bit difficult for the typical reader; hence solutions are presented at the end of the book.

The decision to replace the Galilean

transformation of classical mechanics with relativistic mechanics, and the physical conclusions that followed from this decision, are used to introduce techniques of analysis and points of scientific philosophy. Thus relativity is followed by a brief chapter on the nature of ad hoc theories and another on the use of the operational definition; this sequence in turn sets the stage for the subsequent developments of quantum mechanics.

### Exploring implications

No holds are barred in the discussions and dialogues, which are permitted to go far afield in exploring the implications of the principles that have been adduced. The operational criterion is compared with Jean-Paul Sartre's approach to existentialism, and a dialogue on the use of drugs employs the same criterion:

"What is expanded consciousness? Suppose just for the sake of argument that someone upon ingesting a particular chemical sees little green insects crawling on the wall—insects not seen by people who are free of this chemical. Can this person properly claim he has expanded his consciousness, that the insects are really there, but the drug has improved his ability to perceive them? If it is simply a matter of seeing things not seen by others, then he has certainly met the requirements. Or shall we instead consider only the pleasant sights induced by this chemical as evidence of an expanded mind, and reject the unpleas-

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ant ones? Do we call it awareness when we hear colors and see music, but write it off as a bad trip when the insects come on? Or shall we simply let the subject tell us himself when it is insight and when it is sickness?"

## Teaching by parables

Physics experiments are described, but the reader is not confused with too many technical details of hardware. Often the experiment takes the form of a parable; an explanation of the respects in which the story differs from the details of the actual experiment then follows. The basis for the Heisenberg uncertainty principle, for example, takes the familiar form of an attempt at a perfect microscope, one that will expose the operation of the hydrogen atom. But before the reader must immerse himself in the relevant optical problems, he is prepared by the following parable:

"A small new nation has just been created from the ashes of an old colonial empire, and there are conflicting reports about its democratic processes. You are a reporter who has been assigned the task of determining whether or not there is genuine freedom of speech in this country. The problem is that every previous reporter has been provided with an interpreter and a tour guide, and his interviews with the population have invariably evoked great enthusiasm for the government in power. This is consistent with expressions of support in the news media. There is simply no opposition; perhaps some will eventually develop, but so far the government has managed to obtain a perfect consensus.

It would, however, be interesting to observe this small nation under rather more objective scrutiny; namely, people must not know that they are being observed, and are therefore more likely to reveal their true opinions. In order to achieve such conditions it is necessary that (a) you learn to speak the language without trace of an accent, (b) your appearance is so disguised as to be indistinguishable from that of the natives, and (c) you sneak across the border at night without being discovered. All these requirements may presumably be met. The question is, can you get away with it? Is it possible to observe this nation in its 'natural' state, namely, as it is when it is not being observed by outsiders?

There is one detail which has not been mentioned: How small can a small nation be? If upon arrival you

discover that there are several million people, the plan has a fair chance of success. On the other hand, if there are only a few thousand inhabitants it may become a bit tricky. With a little luck, however, it may still be possible to hide in the population. What if there are only a hundred people? Everyone is likely to know everyone else; it will be difficult to pass as just another native. Perhaps it can be managed for a short time, but eventual discovery is inevitable. Worse yet, what will you do if there are only ten inhabitants in this country? It would be a miracle to 'pass' even for a moment in such an environment. And now we come to the worst of all possible circumstances: Suppose this 'nation' has only one native! Not only is it impossible for a reporter to speak to such a 'population' without being discovered, but the very questions he would want answered have lost their original meaning. Words like democracy, consensus and freedom are no longer relevant. It becomes necessary to ask different questions, to employ new concepts, and to discard old pictures in describing such a situation."

One may choose to question how much physics can actually be understood by someone who has not been prepared over a period of years by a suitable hierarchy of mathematical preparation; it may indeed be somewhat less than some of us like to contemplate. But if members of our society can be made, in the course of their education, to feel less alienated from science and the processes of rational discourse, educators will have done an important part of their job.

I must admit that I undertook this project not entirely without misgivings. One hears in one's mind the voices of physicist friends saying: "You are distracting them. Why be so defensive? If you'd only stick to physics. . . ." One tends, however, always to be guilty of the fallacy of projection. We try to remember how the world looked to us before we knew physics, and then we think we have put ourselves in their place. But I do not believe that we will distract the humanists; they came to us that way.

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