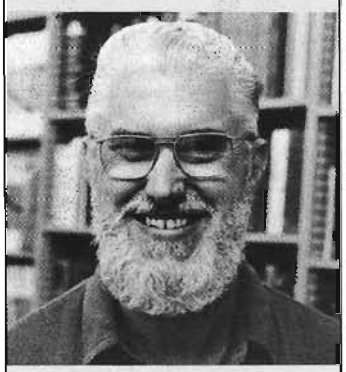
SEARCH

Scientists Who Serve God

He's Fond of Photons



Photons are "particles of light energy." Their interactions with solid materials have interested Richard H. Bube for nearly fifty years. Bube (pronounced "Byoub") is professor of materials science and electrical engineering at Stanford University in California.

Physics: Getting Excited

Dick Bube was born in 1927 in Providence, Rhode Island. For his freshman English class at Brown University in Providence, he wrote a paper on "cold light." The young physics major, you might say, got excited about excitation.

Excitation is a term physicists use to describe the raising of an atom or molecule to a higher-energy state. When excited atoms return to their normal state they emit photons, a process called luminescence. A glowing flask of chemi-luminescent "cold light" is a big hit in science shows. On summer nights bio-luminescent fireflies blink at each other. In fluorescent lights, atoms of mercury vapor excited by electrons emit invisible ultraviolet photons, which excite solid materials coating the tube, which in turn emit lower-energy visible photons. In neon lights the visible light is the output of the gaseous elements themselves. In a form of luminescence called phosphorescence, the light lingers longer after excitation stops.

Dick Bube's excitement and output both lingered. He continued to study luminescence at Princeton University, where he earned an M.A. and a Ph.D. in physics. When he received his Ph.D. in 1950 he had already been working two years on the technical staff of the RCA Laboratories in Princeton. He had also met Betty Jane Meeker and married her (in 1948). From 1948 to 1962 Bube managed á research group at RCA investigating photoelectronic materials. They were especially interested in what might be called the opposite of luminescence: materials whose electronic properties changed when they absorbed photons.

Materials Science: Transition to Academic Life

Technical papers, patents, and his 1960 book, *Photoconductivity of Solids,* earned Richard Bube a reputation in his field. That book, recognized as a classic, was translated into Russian in 1962 and was reissued in this country in 1978. Bube was invited to Stanford as an associate professor in 1962 and became full professor in 1964. From 1975 to 1986 he chaired the Department of Materials Science & Engineering. Fifty students have received Ph.D. degrees under his direction. For the past decade Bube has focused on the photovoltaic effect—on which solar energy cells depend.

As a physicist-turned-materials-scientist, Professor Bube has been working hard to help make solar energy a viable alternative energy source. As a Christian serving God through scientific work, he plays another significant role: exploring what it means to know Christ as personal Savior in a technological age. He puts a lot of thought into presenting and clarifying the gospel to students, colleagues, and the general public. His 50th doctoral student was a seven-year veteran of InterVarsity Christian Fellowship staff work. Besides Bube's four published texts on solid-state physics (each of which begins with a verse of scripture), he has written many articles and five books on Christian faith and its relation to science.

Richard Bube has been a Christian for most of his life. He's still excited about that. Ω

Scientific Investigation

Putting Sunlight to Work

Much of the energy available on earth does come from the sun. Hydroelectric power depends on the sun's heat to evaporate ocean water so it can rain down above dams and flow through electricity-generating turbines. The fossil fuels on which we live so lavishly were once "biomass" nourished by photosynthesis, then heated and compressed into coal and oil. As petroleum supplies dwindle, we must tap the sun's energy in more immediate ways. Solar cells produce electricity directly but are now too expensive for all but special uses, such as running pocket calculators or satellites.

Photovoltaics in Theory and Practice

Solar batteries are photovoltaic devices based on the "photoelectric effect" studied by German physicists at the turn of the century. Heinrich Hertz first noted the effect in 1888 and Phillip Lennard concluded that electrons were emitted by certain materials when light fell on them. In 1900 Max Planck gave his name to Planck's constant, relating the energy of radiation to its frequency. By putting it all together in 1905, Albert Einstein laid the foundation for the new quantum theory.

The same phenomenon whose explanation revolutionized theoretical physics has practical importance in today's search for renewable energy sources. Solar cells require a junction of two suitable materials so that photons can "push" negatively charged electrons into one of them, leaving "positive holes" of missing electrons in the other. Movement of the electrons and "holes" (in opposite directions) constitutes an electric current; their accumulation on opposite sides of the junction produces an electric voltage. Single-crystal solar cells are made by diffusing impurities into hole-controlled or positive (p-type) silicon to convert a thin layer into electron-controlled or negative (n-type) silicon. Or two completely different materials can be joined, such as (n-type) cadmium sulfide plus (p-type) cadmium telluride or indium phosphide.

Needed: Both Science and Engineering

Professor Bube and his associates investigate new kinds of photovoltaic combinations to see what happens at their n-p junctions, hoping to increase solar-cell efficiency. In the best solar cells now in use, about 30 percent of the radiant energy is converted into electrical energy. Bube's research group pays special attention to thin-film polycrystalline or amorphous materials. If certain problems can be overcome, solar cells using such materials could be manufactured at much lower cost than single-crystal cells. Electric power generation by huge solar collectors would then be economically competitive.

Richard Bube already has over 250 research publications and three patents on photoconducting materials and devices. He has written three technical books in addition to his 1960 text on photoconductivity: *Electronic Properties of Crystalline Solids* (1974), *Electrons in Solids* (1981; 2nd edition, 1988), and *Fundamentals of Solar Cells* (1983), the latter written with a current coworker, Dr. Alan Fahrenbruch.

Has Bube thought about retiring? Well, yes, but there are always some new experimental results that need looking into. Being able to make cheap, efficient solar cells wouldn't solve all of our energy problems, he admits, but "it would be nice to get that far before we run out of oil."

Ω

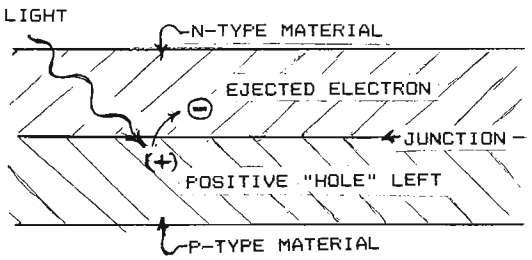


Diagram of the action in a typical photovoltaic cell, as solar radiation is converted into electrical energy.

"VERUM DICIT"

Some big American universities have begun to admit that they've neglected teaching. Well-known professors may insist that teaching undergraduate classes would take too much time from their research. Others do teach, even though rewards and prestige are more likely to come from research. Some, like Dr. Richard Bube, transmit wisdom as well as knowledge to students.

In 1967, Bube initiated a 10-week, academic-credit, elective seminar at Stanford on "Issues in Science and Religion." Each year between 15 and 25 students, most of them with some personal connection to Christianity, have chosen the seminar and then shared their enthusiasm with the next generation of Stanford undergraduates.

Participants have examined ethical issues from the viewpoints of science and of Christian faith, writing papers on their own integration of those insights. Bube's seminar dispels the mistaken idea that one must make a choice between "science and the Bible." Both are important.

Many colleges and universities have Latin mottoes like *Fiat Lux* ("Let there be light") or *Lux et Veritas* (Yale's motto, "Light and Truth"). Dick Bube studied at Brown (*In Deo Speramus*, "We trust in God") and Princeton (*Dei Sub Numine Viget*, "He grows strong in God's presence"), and teaches at Stanford (*Verum Dicit*, "He speaks the truth").

Stanford's expert on photoelectronics knows what truth is all about. *Verum Dicit.*

Theological Reflection

The Light of the World

The Bible is full of references to light, from "God said, 'Let there be light'; and there was light" (Genesis 1:3) to the final prophecy of a new heaven, new earth, and "New Jerusalem," a city with no need of sun or moon, "for the glory of God is its light, and its lamp is the Lamb" (Revelation 21:22).

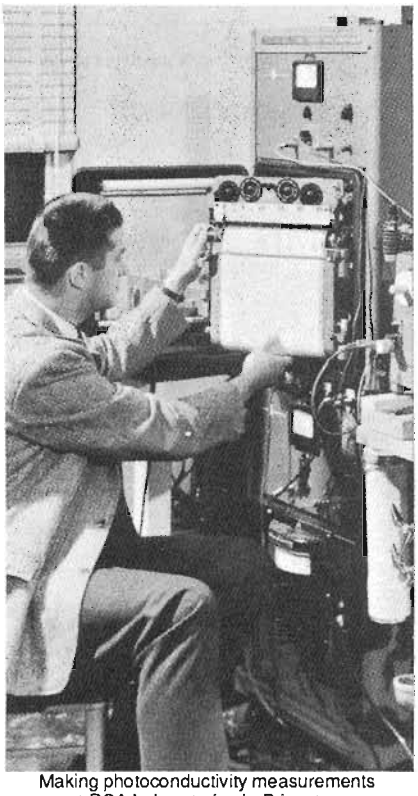
Jesus Christ, Light of the World

One biblical use of the word *light* is still common, as a metaphor for revelation, or "enlightenment." We say that a lecture "shed light" on a subject, or was "illuminating." Biblically, light also stands for God's moral perfection, or goodness in a more general sense. It is frequently contrasted with the darkness of evil, accompanied by warnings not to let God's light flicker out (Luke 11:33-35).

In John's Gospel, both meanings are applied to Jesus Christ. As the *Logos* or "living Word," Christ was in on God's creative activity (John 1:1-5), then came into the world as "the true light" to enlighten all people. Further, "to all who received him, who believed in his name," his life of grace and truth became our light (John 1:6-18), which can be passed on. Christians are called "children of light" who belong to the day (1 Thessalonians 5:4-11) and should "cast off the works of darkness and put on the armor of light" (Romans 13:11-14).

How Does the Creator Interact with the Created World?

Science began several hundred years ago with a focus on mechanics. In the 20th century, relativity and quantum theory upset classical cause-and-effect determinism. Einstein's work on the photoelectric effect was one of the first indications that the physical world is not a simple "clockwork." When mass turned out to be equivalent to energy, a world of events or relationships (or "information") began to make as much sense as a world of material particles.



Making photoconductivity measurements at RCA Laboratories in Princeton, New Jersey, 1959.

The Bible pictures God as *transcendent* (above and beyond his creation), but at the same time *immanent* (interacting with it in significant ways). One challenge for Christians in an age of science is to find ways of decribing God's action in the world that mesh with, or at least do not violate, what we know to be true from science. Because God is transcendent, any description of God's influence must be in the form of an analogy or metaphor, but it should be a *good* metaphor.

One can be sure that a Christian materials scientist like Richard Bube, as he investigates how light causes its effects in physical materials, also thinks about how "the Light of the world" puts grace and truth to work. When believers are spiritually enlightened, for example, what happens? We know the importance of "junctions" in solar cells; could it be that a dual kind of contact (with the world in one direction and the Holy Spirit in the other) is necessary for Christians to function as effective "cells"? As an individual, how does one become more efficient at converting "light from the Son" into good works? What happens when individual cells are linked together to form the "body of Christ" (1 Corinthians 12:27)?

The church, functioning properly, seems to bear some analogy to a large array of solar cells—an alternative source of power (Acts 1:8).

Ω

"LET IT SHINE"

"This little light of mine, I'm gonna let it shine." So goes a children's Sunday school song about being a faithful witness. Richard Bube has let his faith shine through five specifically Christian books. In fact the first book he wrote was *A Textbook of Christian Doctrine* (Moody, 1955).

The Encounter Between Christianity and Science (Eerdmans, 1968) and *The Human Quest: A New Look at Science and Christian Faith* (Word, 1971) were both major contributions. Regrettably, both went out of print after selling only a few thousand copies. (That happens to many good books on science and faith these days, partly because of a change in the way publishers' inventories are taxed.)

Still available (from ASA, address on p. 4) is *Science and the Whole Person: A Personal Integration of Scientific and Biblical Perspectives* (ASA, 1985), a collection of Richard Bube's articles from the *Journal of the American Scientific Affiliation.* He edited that journal from 1969 to 1983 and still contributes articles and reviews to it. The ASA journal is now called *Perspectives on Science and Christian Faith.*

Not yet in print is Bube's most recent book, *Shaping the Future: Modern Science and Christian Choices.*

Christians in technical occupations are concerned about being whole persons, but may differ in the way they look at their careers. Some strive to use their training to meet human needs in practical ways. Others place importance on bringing biblical insights to their profession, or on bearing witness to the scientific or academic communities. Some see their calling as no more specialized than that of other Christians, simply to live out the gospel within one's family, church, and community.

A Special Kind of Generalist

"Hey, no fair! Dick already stands 6'7" to Betty's 5'2"."

Stanford professor Richard H. Bube has done all of those things. In his technical work he has ranged from the highly theoretical to the intensely practical. He has written theological works but also served the church in ordinary ways, teaching Sunday school classes and sponsoring campus Christian groups. He and Betty have raised two sons and two daughters: a lawyer, a mathematician, a psychologist, and an accountant.

Dick Bube has contributed his editorial skills not only to the Christian *Journal of the American Scientific Affiliation* but also to the *Annual Review of Materials, Materials Letters,* and *Solid-State Electronics*. He has presented papers both at Christian conferences and at many science and engineering societies. He has given technical lectures at various American and European universities but also taught at Fuller Theological Seminary and Regent College. He has lectured on science and Christianity at over 60 colleges and universities, frequently as a Staley Distinguished Christian Scholar Lecturer. He has served as elder, teacher, or lay preacher in local churches affiliated with Lutheran, Presbyterian, and Covenant denominations.

Needed: Both Evangelism and Social Responsibility

In *The Encounter Between Christianity and Science* (1968), Bube wrote that although the church's basic responsibility is to lead people to Jesus Christ, that responsibility cannot be met if each individual Christian is not fundamentally concerned about the needs of the whole person and of society. In 1985 he made a similar plea for balance in *Science and the Whole Person.*

Bube has also addressed a specific group of Christian young people, those who might want to follow in his academic footsteps. He called a recent article "So, You Want to Be a Science Professor!" and subtitled it "The Education Business: Things My Mother Never Told Me" (*Perspectives on Science and Christian Faith,* Sept 1989, pp. 143-151). After offering much practical advice, he concluded this way:

> "There are few greater challenges than for a Christian faculty member to stand gently firm for Christ in the midst of a secular campus. Among colleagues whose academic achievements are an almost impenetrable insulation against the message of the gospel, he [or she] lives daily to be heard and known as a person of integrity and intellectual responsibility, who can be trusted in professional and personal matters, but who calls colleagues and students alike to a higher relationship and a more encompassing good. There are few greater challenges—but there are few greater opportunities."

Let your light so shine before [others], that they may see your good works and give glory to your Father who is in heaven (Matthew 5:16).

Ω

Thoughtful Worship

Science and the Whole Person

SEARCH (No. 10) was prepared by Walter R. Hearn of Berkeley, California. Design by Nancy C. Hanger; layout by ASA managing editor Rebecca Petersen. Opinions expressed in SEARCH are those of individuals and may not be representative of the entire ASA membership. Scripture quotations are from the Revised Standard Version unless otherwise noted.

©1990 by American Scientific Affiliation. All rights reserved.

SEARCH brings scientific questions to the attention of pastors and the Christian public by focusing on the work of Christians in science. SEARCH is an occasional publication of the American Scientific Affiliation (ASA), Robert L. Herrmann, executive director. To obtain a free single copy, send stamped, self-addressed envelope to: ASA, P.O. Box 668, Ipswich, MA 01938. Be sure to state the number of the issue being requested. Multiple copies to one address: 15¢/copy plus $1.50 postage and handling charge; prepaid orders only, please.

The 1989 version of ASA's 48-page guidebook, *Teaching Science in a Climate of Controversy,* helps teachers cope with questions of science and religion. It is available postpaid from ASA at $6 for one copy, $5 each for 2-9 copies, $4 each for 10 or more copies.

For information on ASA Annual Meetings, other ASA publications, or how to become a **Member, Associate,** or **Friend** of ASA, write to: **ASA, P.O. Box 668, Ipswich, MA 01938.**