Physics

Dietrick E. Thomsen reports from Baltimore at the meeting of the American Physical Society

Superconducting silicon

Under extreme pressure (thousands of atmospheres) solids can change their crystal structure and with it their properties. For example, carbon becomes diamond rather than graphite. Considering silicon, earth's most abundant element and the one on which much of modern technology depends, three physicists from the University of California at Berkeley, Michel M. Dacorogna, Kee J. Chang and Marvin L. Cohen, calculated what would happen to it under pressure.

At normal pressure silicon has the same crystal structure as diamond and is, electrically, a semiconductor. Under more and more pressure, Dacorogna, Chang and Cohen predicted that silicon should go through a series of metal-like crystalline states — first the configuration known as beta-tin, then simple hexagonal and finally hexagonal close-packed. In these configurations and at sufficiently low temperatures silicon should become a superconductor.

As they were about to present their calculations to the American Physical Society meeting, they received news from a French group that is performing actual experiments with pressured silicon. Early results show that under pressure silicon becomes a superconductor at a temperature of 5 kelvins. With more pressure applied, the transition to superconductivity occurs at a higher temperature, 8 kelvins. Cohen says these two figures correspond to his group's calculations. He expects that the hexagonal close-packed state will show an even higher superconducting transition temperature. In the meantime, he and his theoretician colleagues plan to start a calculation for another common semiconductor, germanium.

The French experiments are done by putting a minute piece of silicon between two anvils made of diamond and clamping on the pressure. Then the sample is dropped into a Dewar flask for chilling. The hard part is putting electrodes on the sample to measure the conductivity.

Taking no chances

The trend of physics over the last 80 years has been to introduce randomness and uncertainty into more and more processes that classical physics considered well determined. Now comes an instance of the reverse. Vladimir Vulovic and Richard E. Prange of the University of Maryland in College Park propose that a process commonly thought to be random is in fact well determined by its initial conditions. Their example is the flipping of a coin.

Coin flipping has been considered the epitome of a random and chancy process, used as an example by students of games of chance since Blaise Pascal. Expressing surprise that it has taken three centuries to figure the contrary, Vulkovic and Prange argue that coin flipping obeys Newton's laws, and that each flip depends on the impulse given the coin by the thumb and the height above the floor from which the coin starts. Any randomness, they say, is not in the flipping itself, but in imprecise knowledge of the starting conditions. If you could know the impulse given by the thumb in a particular case, or had a well-calibrated mechanical flipper, you could predict how the coin would fall (ignoring effects of the air and assuming a perfectly flat floor). The same considerations should apply to the fall of dice or the spin of a roulette wheel, they propose.

The mathematical source of this odd result comes from an extension of the work of Pascal and Pierre de Fermat, which is that many equations may have completely determined solutions (as in this case) and yet give "unpredictable" and truly random results. This happens, according to Vulovic and Prange, "because predictions of the future depend with excruciating sensitivity on the starting data.... However, even if precise predictions are not in practice possible, the equations can predict probabilities of various outcomes."

Technology

Automation in motion

The swimming of fish, the flexing of a runner's foot, the movement of a robot reaching for a tool are all examples of motions that researchers want to analyze. In many cases, the analysis is still done by filming the action, projecting the images on a screen and manually measuring changes in position from one frame to the next — a tedious, time-consuming process. Now, motion analysis is speeding up with the introduction of sophisticated, computer-assisted video systems that automatically track and tabulate the trajectories of moving objects.

In the ExpertVision system developed by Motion Analysis Corp. of Santa Rosa, Calif., a video camera views, for example, a group of microscopic organisms flitting about in a drop of water. An electronic device, which reads 2,000 different shades of gray, converts each incoming, analog picture into a digital image that shows only the outlines of the objects of interest. Everything darker than a certain gray level, selected according to the contrast between the objects and their background, is represented by a one; everything lighter than that is a zero.

At 60 frames per second, the video processor tracks up to 250 separate moving objects at the same time, providing a list of coordinates for all of their outlines. A computer program organizes these data by linking the coordinates into groups that represent individual objects. A researcher can then ask for anything from a simple plot of a particular particle's path to a complex statistical analysis.

"The key to bringing an instrument like this to product status," says William G. Hand, one of the company's founders, "was the development of high-speed supermicrocomputers." These machines were needed so that computations could be done quickly enough to allow convenient motion analysis. The image-processing software itself, however, conceptually hasn't changed much, says Hand. It was first developed more than a decade ago by John O.B. Greaves when he was a graduate student at the University of California at Santa Barbara.

"The system can be used in virtually any application in which motion is a factor," says company president Sue W. Smith. One system, for example, is now being used by a shoe manufacturer to improve the design and performance of its running shoes. Another, at the University of California at Davis, tracks the motility of sperm in human fertility studies.

A rival motion analysis system, SELSPOT II developed by Selective Electronic, Inc., in Valdese, N.C., uses a different method for capturing the initial images. Infrared light-emitting diodes are attached to a number of points on, say, the head of a golf club or the body of a dancer. The diodes flash on and off in predetermined sequences. A special camera, which detects only diode-generated light pulses, automatically registers the coordinates where the light strikes. The system easily determines the location of the point on the moving object from which the light initially came. These data go to a computer where the motions can be analyzed in detail.

A shot of lime for cleaner burning

Limestone injected into a coal-burning furnace acts like a chemical "sponge" that absorbs sulfur impurities before they escape into the atmosphere. Normally, this method requires large quantities of limestone. However, recent U.S. Department of Energy tests show that if a special form of limestone is used, only one-third as much limestone is needed to reduce sulfur emissions.

This material, called "pressure-hydrated" lime, is made by mixing water and calcium, then compressing and heating the mixture. The resulting particles are very small and together have an extremely large surface area, making them more effective in capturing pollutants like sulfur dioxide. The powder is simply shot into a furnace through pipes that carry compressed air.