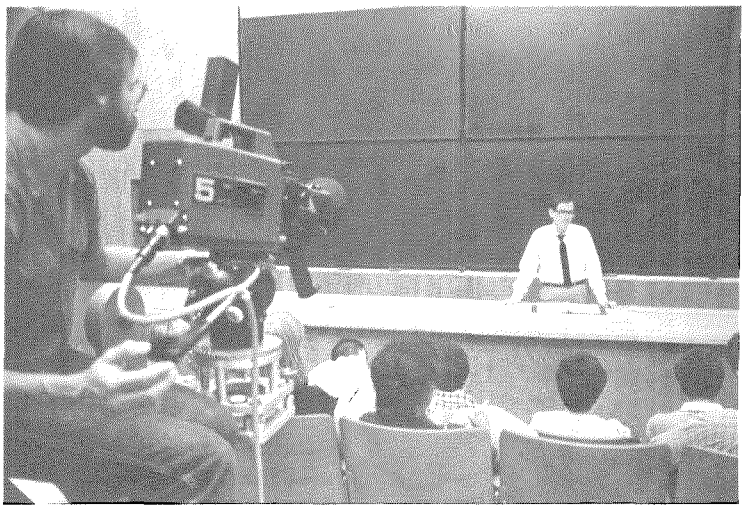
Physics on the Tube

"The Mechanical Universe" is in production at Caltech and Knott's Berry Farm



Although the TV physics course begins in the lecture hall, it departs after a couple of minutes to more exciting locations, for example, the Corkscrew at Knott's Berry Farm.

"OKAY, STUDENTS, walking positions, please," says the director. "Take it all the way through this time. Remember to take notes. Stand by . . . action."

The camera rolls. Students file into the physics lecture hall, 201 Bridge, more brightly lit than usual, and take seats in the first two rows. The next several rows have been removed to accommodate the cameras, lights, and other equipment. David Goodstein, professor of physics, who has been drawing circles on the blackboard as the students entered, begins his lecture.

"I don't know who invented the wheel, but the circle was discovered independently by primitive peoples all over the world. Often it had mystical significance, associated with the horizon, the sky, and the gods. Gradually, myths acquire complicated traditions and fancy language. Then they become known as philosophy."

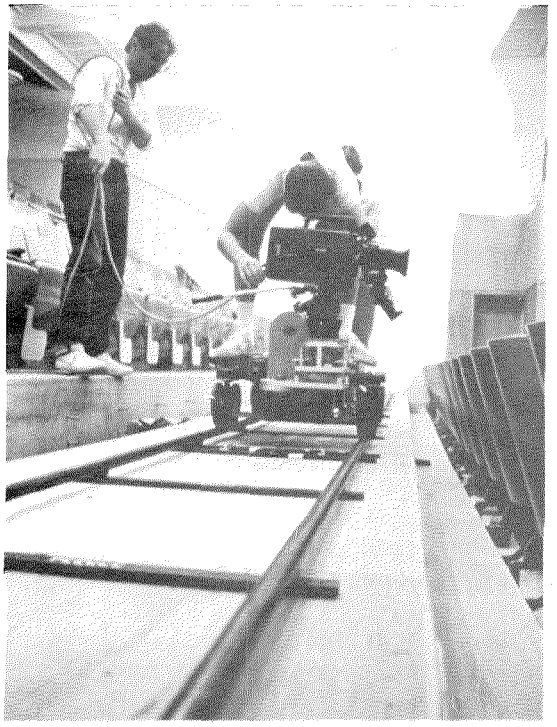
Goodstein goes on to Plato and the idea, which "stopped astronomy dead in its tracks for 2000 years," that the heavenly bodies move around the earth in perfect circles at uniform rates. The subsequent effort to explain actual observations led to the contrivance of epicycles, or circles centered on circles . . .

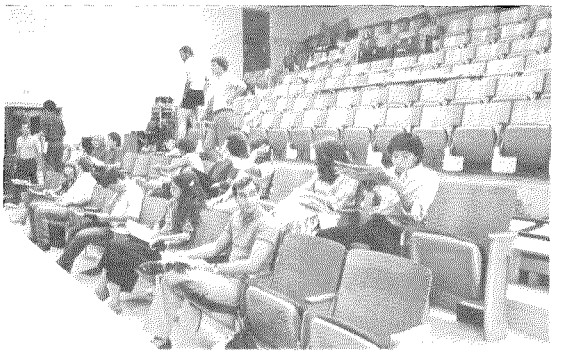
"Cut."

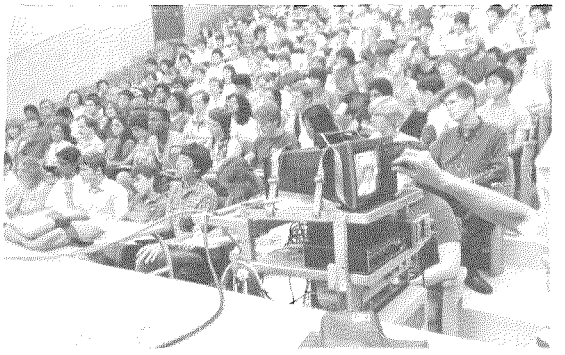
It's scene 1, take 1, of program 9 of "The Mechanical Universe," Caltech's current venture into show business — an introductory course in classical mechanics developed in cooperation with the Corporation for Community College Television. The show is being produced and directed by Peter Buffa, and Caltech's Don Delson is project manager. Funded by $2.1 million from the Annenberg/CPB Project (a joint effort of the Annenberg School of Communications and the Corporation for Public Broadcasting), the series of 26 half-hour programs is part of a plan to create innovative college-level courses using the unique capabilities of telecommunications.

These unique capabilities will enable the student viewer to flee the lecture hall for other sites that provide often amusing illustrations of physical principles (the program on the law of falling bodies begins on a window washer's scaffold high on a Los Angeles skyscraper) and dramatized historical sequences (Newton's apple orchard, for example, offers some opportunities for humor). Computer graphics by the Jet Propulsion Laboratory's James Blinn include lively ballets of equations more like a video game than the static page of a math book.

But it's not all fun and games. "The Me-







Removing rows of seats in 201 Bridge accommodated a track for the camera (far left). For most of the classroom shooting over the summer, only two rows of "students" were necessary for the foreground. When Caltech students returned in the fall, a whole hall's worth were hired (below) for "student reaction" scenes to be spliced into the sequences taped earlier.

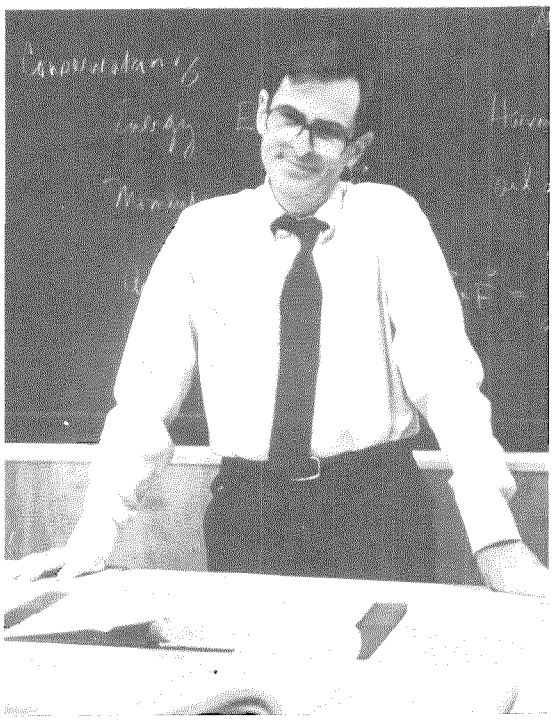
chanical Universe" will offer a rigorous semester's worth of Newtonian mechanics along with all the requisite calculus. This is, after all, Caltech. The idea sprang from Goodstein's version of Physics 1, which he taught from 1979 to 1982, and which has become a local legend for its spicing of wit along with the solid stuff. Two textbooks are being written to accompany the program — one for students in nontechnical fields and the other for engineers and science majors. Early chapters of the latter, in manuscript form, made their debut this fall in Caltech's Physics 1, currently taught by Steven Frautschi, professor of theoretical physics. Frautschi, Tom Apostol, professor of mathematics, who received one of the 1983 undergraduate awards for outstanding teaching, and Richard Olenick, visiting associate in physics from the University of Dallas, are the authors of the text.

Each of the TV programs will begin and end in 201 Bridge with Goodstein in his accustomed place at the blackboard — for example, drawing circles in program 9, "Moving in Circles." But the lecture introduction lasts only two minutes ("the audience falls asleep after two minutes"), and then the narrator and picture show take over.

"Moving in Circles" must put across the concept of the derivative of a vector, worked out by application to uniform circular motion. Derivatives, vectors, and integrals will have already been introduced in earlier programs, as well as universal gravity and Newton's law, which determine planetary orbits (which are almost uniform and almost circular). Program 9 puts all of that together and introduces concepts necessary to understand later programs on rotating bodies and angular momentum — not an easy task in half an hour. How do you get such complicated abstractions across and make them entertaining as well?

Ideas come from a number of sources. Since the format of the series is based on a Caltech course, the starting point for each of the programs is Goodstein's "phantom" lecture on the subject — phantom because most of the program isn't really a lecture at all. Goodstein oversees the evolution of the script and makes all final decisions. His phantom lecture for "Moving in Circles" moved on from epicycles to Copernicus, whose revolutionary idea, says Goodstein, was actually an attempt to make the universe more Platonic, the motion more uniform. From there Goodstein launched into the math — the position of an object in uniform circular motion expressed as a vector quantity and its velocity and acceleration as derivatives of vectors.

The TV program, however, takes off into the mystical significance of the circle in primitive cultures, sneaks into vectors via computer animation, returning later to Copernicus. Story editor Jack Arnold assigned the script of program 9 to Deane Rink, one of six professional writers working on the show. For guides the



Program 9 of "The Mechanical Universe" will star amusement park rides as well as David Goodstein.

writer had the phantom lecture, the relevant chapter of the textbook, and a program content outline developed by the Caltech team suggesting the major concepts to be conveyed, real-world examples, existing film footage, and computer animation possibilities.

"From a physics/math/historical standpoint, the key work has been done for you," Arnold wrote to Rink. "So you 'merely' have to understand and to implement the scholars' blueprint . . . Use (your creativity) to take the blueprint and create a magnificent structure. A story line that flows, a narration that enlightens, provokes, entertains, a collection of pictures that illustrate, captivate, make circular motion spin in the viewers' mind."

Meanwhile, back at Caltech, other imaginations were also busy with the problem. In a science writing course taught three terms last year (and again this year) by Ed Hutchings, lecturer in journalism and former editor of *E&S*, undergraduate veterans of Physics 1 offered their own ideas of communicating physics in a visually entertaining manner. Their treatments and scripts were mainly exercises for the course, but occasionally student-generated ideas were assimilated into the show. For "Moving in Circles" several students wanted to illustrate vectors with a slingshot — a dramatization of a Grecian warrior or David and Goliath, with the whirling sling fading into animated equations. Goodstein, who usually sat in on the class, thought this idea was "good pedagogically," but "the TV people will want more scenery than a swinging sling. They have to fill up 23 minutes with pictures."

Tracy Furutani, now a senior, wrote a complete script for program 9 with suggestions for narration, dramatization (which facetiously included Copernicus's mistress and Plato in his native ambience surrounded by "scantily clad slave chicks"), computer animation, music ("Circles" by rock musician Peter Townshend), and location footage (a machine shop used in an earlier program, which would cut production costs). Furutani's script wasn't used, but it was especially confident and correct on the math, according to Goodstein, and this — not the nearly nude slaves — earned him a summer job as a math consultant to the professional writers.

The final "concept sequence" (the setting for the major portion of location filming) for "Moving in Circles" actually did come out of the class. David Sahnow, also a senior, suggested an amusement park: "Show rides that have circular motion: merry-go-round, Ferris wheel . . . the one where the rider sits in a swing and is spun around, and the one where the riders are strapped into a rotating cage, which is turned vertically."

Sahnow's amusement park was written into the script. Completion of the script, which was assigned in May, was supposed to take 50 days. The writer's first of several drafts elicited from Goodstein: ". . . it seems to me the main problem is that the sweep of the history is so grand that the math and physics come off as annoying intrusions. The point of the program should not be the importance of the circle in human history, but rather how to master circular motion with the mathematical tools in our arsenal.

"The point of the amusement park is to put us into circular motion so that we can sense the effects. Another more subtle and entertaining point is the role of the circle in ancient religion and mythology played off against its use in our modern secular religion of pleasure. It can also get us into and out of computer animations of the mathematics.

"The circle in astronomy connects this program to the rest of the series. It also sets up one of the payoffs of the program: Once we realize that uniform circular motion involves constant acceleration toward the center, we have a simpler, more effective description of the point Newton worked out with great difficulty in program 8: how gravity keeps the moon in motion around the earth."

In the final script the scene cuts from the lecture hall to the rising sun and its symbolism to ancient peoples from Assyrians to American

Indians. A computer-animated vector superimposed on a circle inscribed on the ground with a rope and stake leads into the mathematics — but not for long, as the amusement park makes its first entrance. Plato, represented by a rotating bust, and his uniform circular motion of the heavens soon appear, followed by another cut to the amusement park and a distorting mirror in the house of horrors. ("The Platonic ideal was imposed upon the nature of reality. If reality wasn't mirrored ideally, it was a reflection of incorrect perception.") For the rest of the 23 minutes, historical elements (Ptolemy, Copernicus, Newton) and the amusement park rides are intercut with computer animation of planetary orbits, rotating vectors, and dancing derivatives, until finally Newton solves the riddle of why, if the earth's gravity makes the moon accelerate, it moves at nearly constant speed (the answer lies in the directions of the vectors).

Newton's study dissolves to the amusement park again, which dissolves into animation of traveling in space, and suddenly the viewer will be back in the lecture hall, where Goodstein is changing the subject. A rather puzzling discussion of medieval torture methods (burning at the stake, drawing and quartering) closes the program, including the impact of the mere threat of torture, which did in Galileo. Goodstein ends:

"You might be wondering why I'm lecturing on such a bizarre subject. It has to do with introducing our next topic, which is the use of force."

The scenes in Bridge were videotaped in August (before real classes began), and location shooting took place this fall, mostly at Knott's Berry Farm. Program 9 will be completed by next spring, and the entire series of "The Mechanical Universe" is scheduled for broadcast in 1985.□ — *JD*