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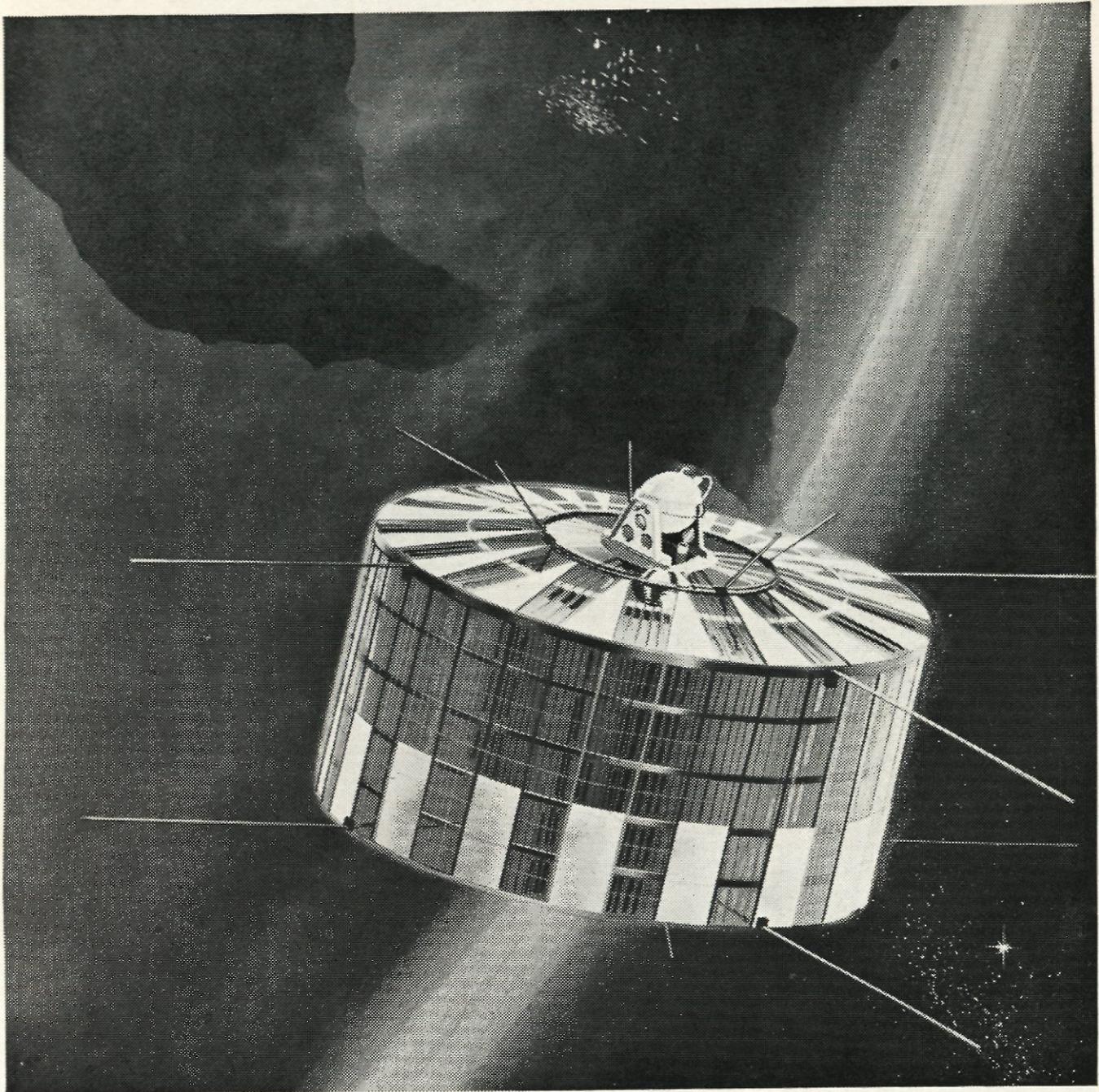


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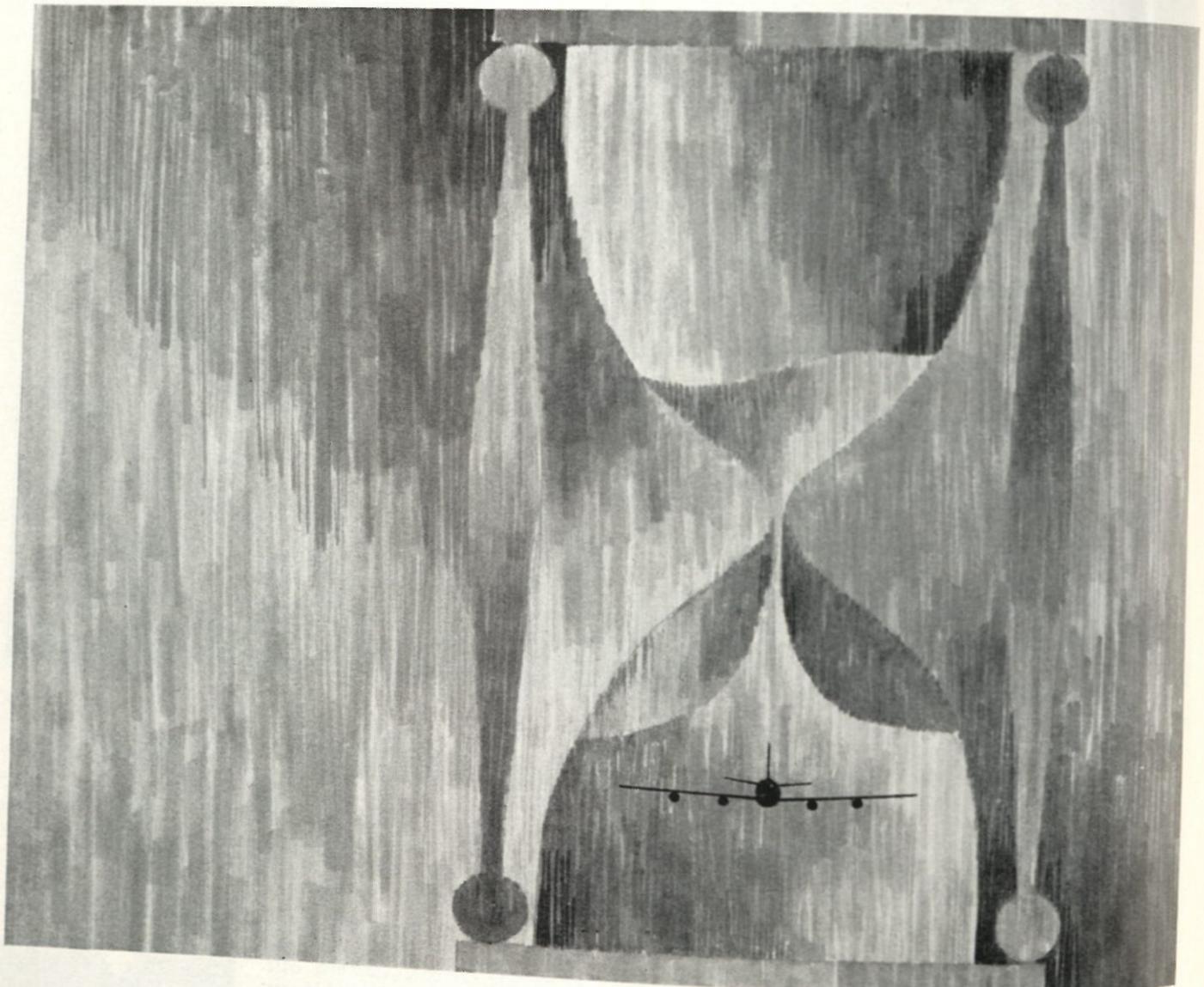


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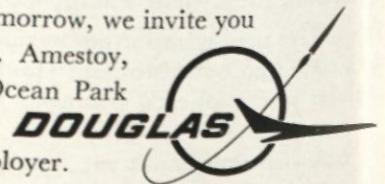
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The COLORADO Engineer

UNIVERSITY OF COLORADO, BOULDER, COLORADO

VOLUME 59

NUMBER 4

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Our cover depicts the University of Colorado's Television Studios.

Member of Engineering College Magazines Associated, J. Chumley, Chairman, Louisiana Polytechnic Institute, Ruston, Louisiana.
Circulation: 2500. Published four times a year, on the fifteenth of November, January, March, and May by the students, faculty, and alumni of the College of Engineering.
Publisher's representative — Littell-Murray-Barnhill, Inc., 369 Lexington Avenue, New York 17, N. Y., and 737 North Michigan Avenue, Chicago 11, Illinois.
Entered as second-class matter March 9, 1916, at the Post Office at Boulder, Colorado, under act of March 3, 1879.

OUR LEADERS' EXAMPLE

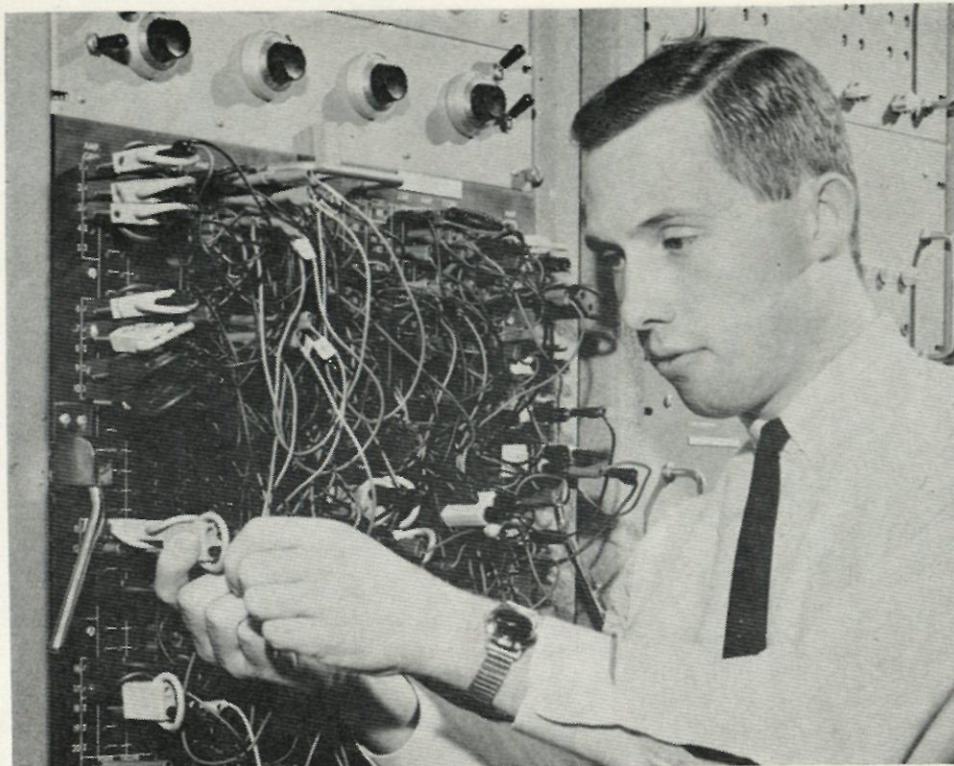
As students on this campus, all of us have been aware of the seemingly endless bickering that consumes the time and energy of each of those various factions which claim an altruistic interest in this University and the students within it. Most of us have been content to allow these factions to grind their axes on the stonework of our institution and then to pass, unmissed, from the newspaper headlines. Normally, our only comment is a passive observation about this or that ridiculous statement, untenable position, or pitiable lack of knowledge.

Yet, in spite of, or perhaps because of, the legion examples of apparent intolerance that reach our ears, many of us readily grasp those same weapons of idiocy when we as individuals or we as a department within the college feel insulted by some other department. Most of us identify ourselves intimately with our particular department and thereby gain a security of numbers and a professional loyalty to our colleagues. This is good only so long as we are not blinded by that security and loyalty to what else exists in the rest of the world. The once great controversy between the East and West ends of the campus has finally begun to die a much too slow death. Be happy? No! The engineering students began to pour the same energy into interdepartmental conflicts. For a while, the rivalry was healthy. On occasion an engineer would be so radical as to produce an original non-technical thought. Now, however, the thinking has stopped and only clichés remain.

The most notable of these cliché-ridden rivalries is that between the students of Physics and those of Engineering. The battle-lines are drawn at "Physics discovered the real world" and "Engineering invented Physics to study falling apples." The battle-lines once fortified with reasoned knowledge, the common tool of both fields, are now strengthened by weak rebuttals that eventually reduce to an anemic Bronx cheer. The bickering so passively condemned in campus politics is repeated without any trace of thought. Which side is right? Is either side right? Instead of wasting time and energy, and more important, losing real knowledge because of disrespect, we might refresh the founders and contributors to each method of thought. A partial list would include Coulomb, Da Vinci, Descartes, Edison, Euler, Franklin, Hooke, Kelvin, Newton, and Rankine. Were they Physicists or Engineers?

—LARRY HUSTON.

Richard E. Covert, Iowa State BSME '62, utilizes an analog computer to study heat transfer transients and their effect on the control mechanism of a mobile military compact reactor being developed by the Allison Division of General Motors under contract to the Atomic Energy Commission. Covert is one of several young engineers now engaged in various studies connected with nuclear powerplant engineering programs at Allison.



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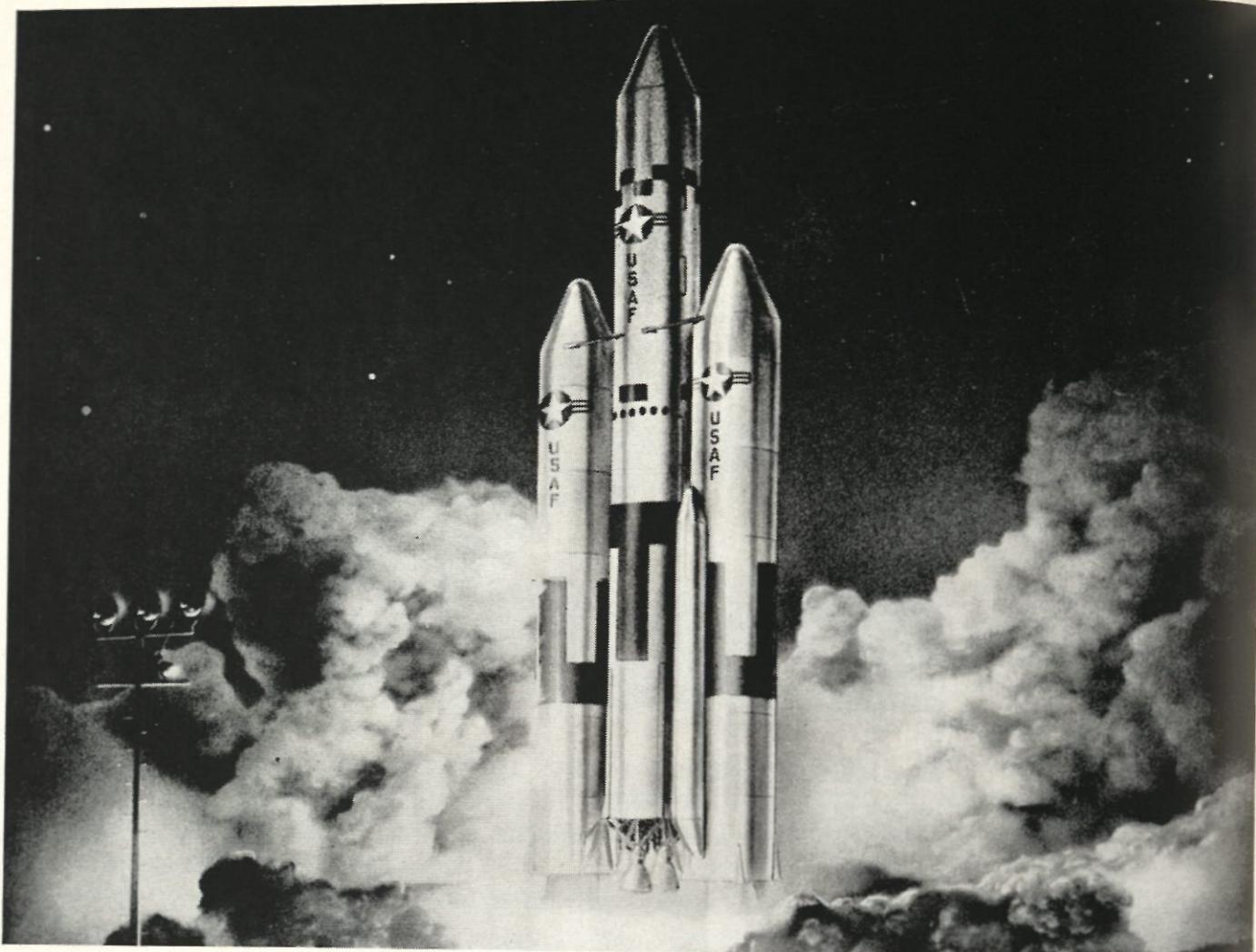
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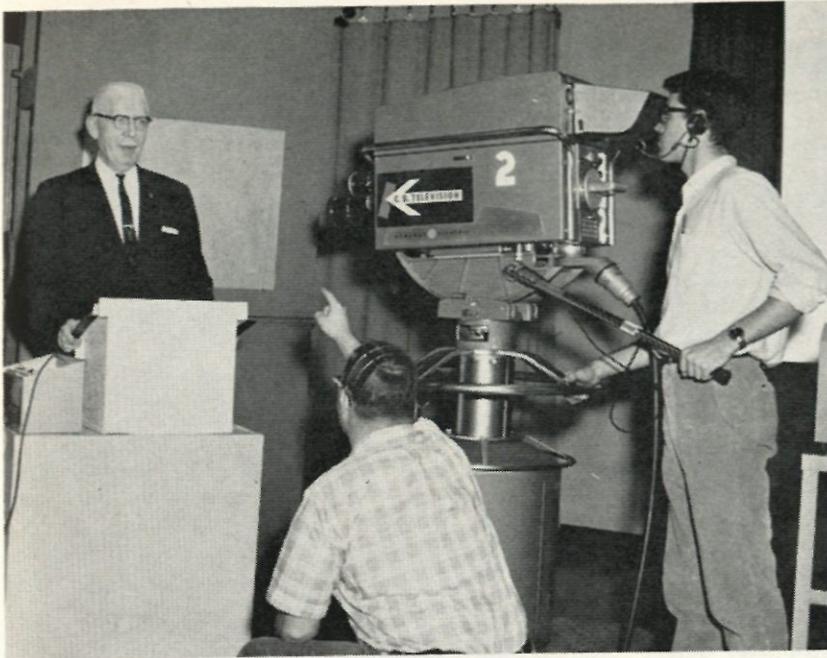
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TELEVISION

JON SWANSON

"TV Studios? Where are they?" is usually the reaction I receive when I mention to someone where I work. The purpose of this article is to dispel some of the mysteries about where we are and what we do in the Department of Radio and Television.

The Department is part of the Bureau of Audio-Visual Instruction, which in turn operates under the Extension Division of the University. The Bureau, in addition to its Radio-TV services, operates a film library containing educational films of all types for instructional use at all levels, elementary to college; a tape duplicating service which employs Ampex 3000 series high-speed duplicators for the reproduction of quarter-inch magnetic tapes, and a library of such tapes for classroom use; a graphics department which prepares slides, charts, graphs, etc., to be used with visual teaching aids such as slide or overhead projectors; and an equipment department which issues and services most of the tape recorders, film projectors, and other audio-visual equipment in use on the campus. The Bureau also does a considerable amount of research in conjunction with educators in the field

of audio-visual educational aids, seeking methods of increasing the scope, quality, and efficiency of the learning process.

There are only four full-time staff employees in the Department of Radio-TV, so extensive use is made of part-time student help to produce the programs and maintain the equipment. Four students, two EE's, one Physics major, and one ex-EE Business major, take care of the technical work in the Department. With one exception, all of the technical crew, including the two staff members, are amateur radio operators, and all hold F.C.C. radiotelephone licenses of one grade or another, mostly First Class. Practical experience in working with electronic "hardware" as well as a fairly good background in theory was stressed in the hiring of these students, as might well be expected in a technical, rather than engineering, job such as this. The technical crew installs, operates, and maintains all of the electronic equipment in the department, and often designs and builds some of the more specialized equipment in use. In addition, some outside jobs are done for other departments of the University, such as the language laboratory we built for

the Department of Spanish, Italian, and Portuguese two summers ago, and the music listening facilities in the library installed the same summer. New projects include another language laboratory for the Department of Slavic and Eastern languages, and working with the Bell Telephone Company on new systems for teaching large groups or groups separated by considerable distances.

As I mentioned, considerable use is also made of students in the production side of the operation. About seven or eight students are employed

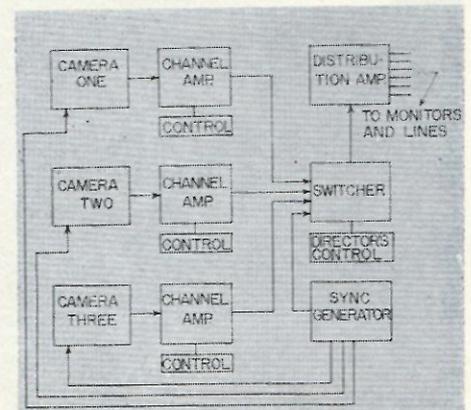


DIAGRAM OF VIDEO SYSTEM

as cameramen, floor directors, audio operators, production assistants; and, for two of the three classes taught, even the director is a student. Most of these students are in the College of Arts and Sciences. Most of the tape recordings the Department makes are of speeches on campus and many of the radio shows produced by the Department are made by these students also.

Studio Location

The Department's Studios are located on the third floor of the Stadium Building, above Gate six. The layout includes: two television studios, a master control room, an audio control room, an announcer's booth, projection room, shop facilities, and an office for the engineering supervisor. Two General Electric Image Orthicon cameras are available for use in either of the studios, which are equipped with so much lighting equipment that a 21-ton air conditioning system was installed to maintain proper temperature for both man and equipment. In addition to the studio cameras, there is a GE Vidicon Camera in the projection room which, through a system of prisms, takes the output of either a dual-drum slide projector or a heavy-duty Kodak 16mm film projector. These three cameras constitute our video sources. All control and switching facilities for this equipment, as well as distribution equipment and power supplies, is located in the Master control room. Also located in the racks in master control is the heart of the whole system, the synchronizing generator, and its spare. This generator, consisting of a crystal oscillator, automatic frequency control to lock the generator to a harmonic of the power line frequency, and transistorized count-down units, provides the synchronizing pulses which keep the scanning in all cathode-ray tubes in the system in step,

and also provides the horizontal drive pulses (15,750 cps) and vertical drive pulses (60 cps, locked to line) which control the frequency of the sweep circuits which drive the yokes on the camera tubes, causing the electron beam to scan the target of the tube. The video information recovered from the changes in beam current as the tube is swept is pre-amplified, and sent via the camera cable to the channel amplifiers in master control, where the synchronizing pulse is added, the signal is amplified, excessive white or black information is clipped, and shading correction is applied, all under the control of the video operator. The video then goes to a picture monitor which the director can see, and also the input of the switcher, a bank of relays controlled by pushbuttons mounted on the director's control panel. By pushing the proper button, the director can select the picture going out on the line from the three cameras available. The director can also switch two pictures to the inputs of a mixing amplifier; the bias on an amplifier in each of the two channels is variable by a lever-actuated potentiometer on the switcher panel. Thus, he can mix the two pictures in any proportion or fade gradually from one picture to another. The output of the switcher goes to a series of distribution amplifiers, which maintain isolation and impedance matching from the switch to the many loads the system must feed, including a line monitor the director watches, monitors in the studios; a line to room 367 in the Stadium which is used as a TV classroom; a line to another distribution amplifier in a closet near rooms 104, 106, and 107 in the Stadium, which are also used as classrooms, and a line which runs through a crawl space under the rim of the stadium all the way around to the field house, where

Mountain States Telephone maintains the first link in a microwave relay to the Denver Extension Center via Sunshine Canyon and the Telephone Company building in downtown Denver. In Denver two rooms on the fifth floor of the Extension Center are presently equipped for television teaching. All direct video lines are properly matched and terminated 75 ohm coaxial cable and all distribution equipment is flat within one db to at least 8 megacycles; this gives a horizontal resolution of above 700 lines per inch on a standard test pattern when all equipment is properly aligned (a stipulation which is met only after a long evening session with a sweep generator and oscilloscope).

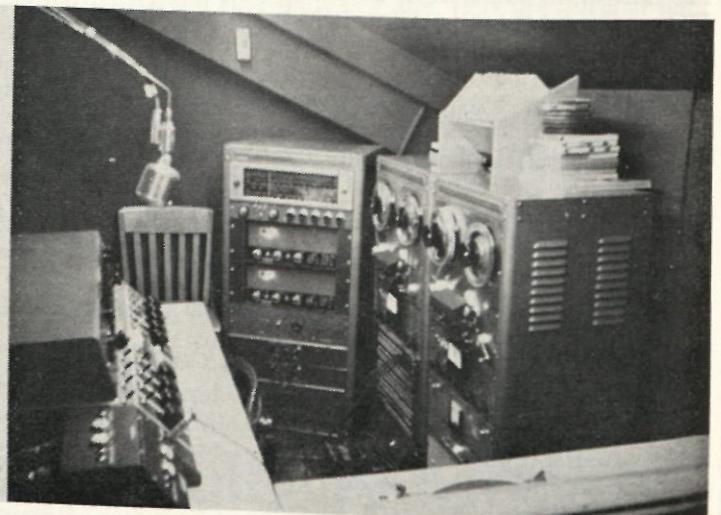
Audio System

The audio system is separate from the video, but parallels it closely. The audio control room contains a GE audio mixing board, which combines the outputs of the microphones in the studio, the Ampex 351 tape decks, the Rek-O-Kut turntable, and other sources, and sends them down 600 ohm balanced lines to the various classrooms. L-pads are provided on all loudspeakers in the classrooms to permit individual adjustment of audio levels. There is also a "talk-back" system from the various rooms back to the studio area, so that students may ask questions of the lecturer. A microphone in the classroom feeds a preamplifier which feeds a line going back up to the audio control room. A push-to-talk button on the microphone actuates a relay to kill the loudspeaker in that classroom to prevent feed-back, and the signal from the microphone is fed into the rest of the audio system through the mixing board, and to the lecturer through an auxiliary amplifier and loudspeaker in the studio. In this manner, a question

(Continued on page 48)



THE UNIVERSITY OF COLORADO'S TELEVISION CONTROL CENTER.



THE AUDIO STUDIO.



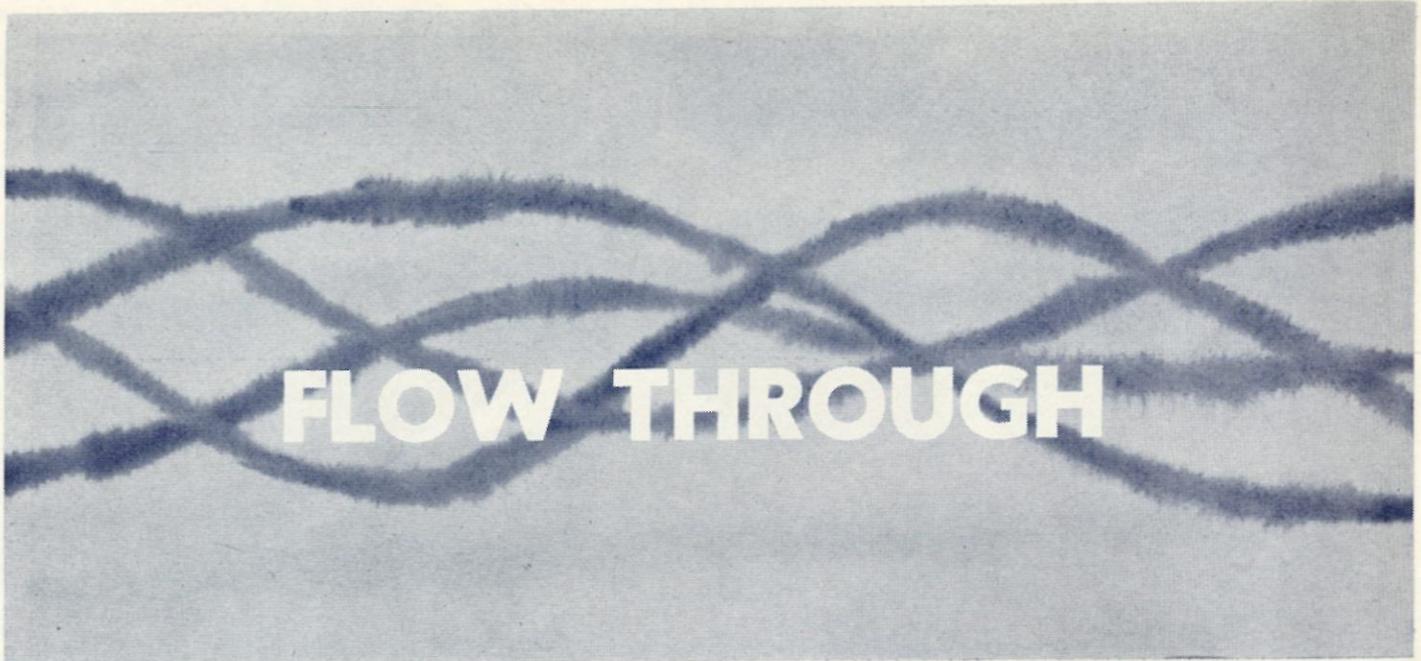
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FLOW THROUGH

The advent of the high-speed computer has only started its revolution in engineering education and engineering design. A machine (IBM 7090) that can add two 8-place numbers in $1/240,000$ of a second is sure to completely alter our approach to the analysis and design of an engineering project. One may start with the basic laws and concepts of the physical and engineering sciences, frequently formulated as a nonlinear partial differential equations; add to these the properties of the materials to be used; then develop the necessary initial and boundary conditions, and come out with a detailed analysis or with studies that lead to an optimized design. Heretofore, because of our inability to handle the fundamental equations in a general way, many simplifying assumptions were made that yield results not necessarily close to physical facts. Every undergraduate engineer should write at least a few simple computer programs before graduating. He may never write another one after graduation—but he is sure to come into contact with and be influenced by the application of computers. An understanding of the simple com-

puter programming techniques could also open many possibilities for interesting work and for advancement in his profession.

This article illustrates one phase of the progress being made by describing briefly the nature of research work in fluid transients as applied to pipes and arteries. The progress being made in this field depends upon research and development in several other fields: the development of mathematical methods for handling nonlinear (or quasi-linear) partial differential equations; the development of computers and of computer languages for the engineers to communicate with the computer; and the development of accurate electronic measuring instruments for recording of simultaneous flow, pressures, and displacements, etc.

Unsteady Flow Through Closed Conduits

The same basic approach is utilized for a water-hammer problem on a large hydraulic project as for pulsatile flow through the arterial system of the body. In unsteady flow the usual form of the Bernoulli equation does not apply—it is only good

when conditions at a point do not change with the time. Velocity, pressure, flow, etc., change with distance x along a tube, as well as with the time t in unsteady flow, and require special mathematical treatment. Two basic equations of mechanics, the continuity equation and the equation of motion, are written for a segment Δx of the fluid within the tube, considering that the tube wall is made of elastic material and that the liquid within it is compressible. Then appropriate expressions are taken to describe the elastic properties of tube and liquid, and are substituted into the two basic equations. The effects of fluid friction are also introduced into the equation of motion in the form of a shear force exerted on the fluid by the wall. The resulting equations are a pair of quasi-linear hyperbolic partial differential equations containing two dependent variables, say, velocity V , and pressure head H , as functions of x and t .

These equations for water-hammer or for flow through arteries differ only in the nature of elastic properties of walls and liquid; except that the artery equations may be written for a tapered tube.

PIPES AND ARTERIES

V. L. STREETER

The two equations¹ may be converted into a family of four total differential equations by the methods of characteristics. The next step is to transform them into finite difference equations so that they may be solved numerically. One additional transformation is then made which permits them to be solved for equal length segments and equal time intervals—called the method of specified time intervals.

One may visualize the solution as being worked out on a grid on the x-t plane, as indicated² in Fig. 1. A

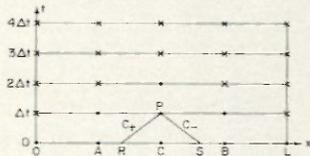


FIG. 1. POINTS INDICATED BY DOTS MAY BE COMPUTED FROM INITIAL CONDITIONS. THOSE MARKED X REQUIRE BOUNDARY CONDITIONS.

$t=0$ steady flow may be assumed to exist, and values of V and H are worked out for each point indicated by a dot on the x axis. By going to specified values of Δx and Δt , only two equations are needed to find V and H at a new point P , if values of V and H at R and S are developed from known points A , C , and B by

HEADS AND VELOCITIES AT TENTH POINTS ALONG THE PIPE												
TIME	TAU	X/L=	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	V ₁₀
.0001.000		H= 107.49	106.75	106.00	105.25	104.50	103.75	103.00	102.25	101.50	100.75	100.00
		V= 3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37
.534 .921		H= 107.49	106.75	106.00	105.25	104.50	103.75	103.00	102.25	101.50	100.75	100.00
		V= 3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37
1.067 .844		H= 107.49	106.75	106.00	105.25	104.50	103.75	103.00	102.25	101.50	100.75	100.00
		V= 3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37
1.601 .770		H= 107.49	106.75	106.00	105.25	104.50	103.75	103.00	102.25	101.50	100.75	100.00
		V= 3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37
2.135 .698		H= 107.49	106.75	106.00	110.70	115.67	121.00	126.70	132.78	139.28	146.20	153.55
		V= 3.37	3.37	3.37	3.32	3.27	3.22	3.17	3.11	3.05	2.98	2.91
2.668 .626		H= 107.49	112.20	117.15	122.45	128.13	134.20	140.67	147.56	154.89	162.67	170.91
		V= 3.37	3.32	3.27	3.22	3.17	3.11	3.05	2.98	2.91	2.84	2.77
3.202 .560		H= 107.49	118.45	124.57	131.61	138.60	145.92	153.23	160.98	169.28	178.19	187.67
		V= 3.18	3.18	3.17	3.11	3.05	2.98	2.92	2.84	2.77	2.69	2.60
3.736 .496		H= 107.49	119.90	127.33	134.83	142.56	150.29	158.29	166.27	174.22	182.25	190.03
		V= 2.97	2.96	2.95	2.94	2.92	2.85	2.77	2.72	2.69	2.61	2.52
4.270 .434		H= 107.49	121.46	129.45	137.51	145.86	154.20	162.48	170.98	179.28	187.28	194.91
		V= 2.75	2.75	2.72	2.70	2.68	2.64	2.51	2.46	2.43	2.33	2.23
4.803 .375		H= 107.49	123.14	131.80	140.52	149.32	158.20	167.20	176.20	185.20	194.20	203.20
		V= 2.47	2.47	2.45	2.44	2.41	2.38	2.34	2.29	2.24	2.14	2.03
5.337 .318		H= 107.49	124.91	134.34	143.80	153.32	162.90	172.50	182.20	191.90	201.60	211.30
		V= 2.18	2.18	2.16	2.14	2.12	2.08	2.04	1.99	1.94	1.88	1.81
5.871 .265		H= 107.49	126.74	136.99	147.32	157.70	168.20	178.80	189.40	199.90	210.40	220.90
		V= 1.86	1.86	1.84	1.82	1.80	1.76	1.72	1.67	1.61	1.57	1.53
6.404 .216		H= 107.49	128.60	139.69	150.92	162.30	173.80	185.40	197.00	208.60	219.90	231.20
		V= 1.51	1.50	1.49	1.47	1.45	1.41	1.37	1.34	1.32	1.29	1.26
6.938 .169		H= 107.49	130.42	142.32	154.32	166.50	178.80	191.20	203.60	216.00	228.20	240.40
		V= 1.13	1.12	1.11	1.09	1.07	1.06	1.05	1.03	1.02	1.01	1.00
7.472 .127		H= 107.49	132.14	144.73	157.50	170.50	183.70	197.00	210.40	223.80	237.20	250.60
		V= .72	.71	.70	.71	.71	.72	.72	.72	.73	.74	.75
8.005 .089		H= 107.49	133.94	147.32	160.90	174.70	188.70	202.90	217.20	231.60	246.00	260.40
		V= .28	.30	.32	.34	.36	.38	.40	.42	.45	.48	.52

FIG. 4

linear interpolation. Points R and S connect with point P by "Characteristic" $C+$ and $C-$ coming out of the method of characteristics. Values of V and H at each dotted point in Fig. 1

may be developed in this manner. At the ends of the tube, however, only one equation in the two unknowns V and H is available from the theory of characteristics, and information on outside, or "boundary" conditions is needed to supply enough information so that both V and H may be obtained. The boundary condition equations may take several forms, depending on the problem. The flow might be specified as a function of time, or the head may be related to the velocity in some manner.³

Figure 2 is a MAD (Michigan Algorithmic Decoder) language statement of a water-hammer problem illustrated in Fig. 3. The reservoir

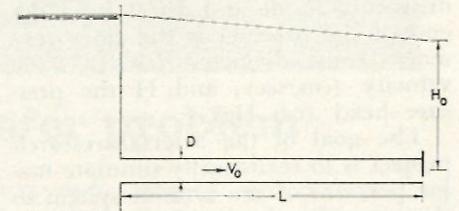


FIG. 3. GATE MOTION AT DOWNSTREAM END OF A PIPELINE CAUSES TRANSIENTS TO DEVELOP.

elevation is assumed constant and the elevation of hydraulic grade line and the velocity is desired for 10% increments of the length. For a valve closure given by a formula, (τ is the dimensionless valve opening, changing from 1 to 0). Fig. 4 shows the form in which the computer prints out the solution to the problem. The valve is located at $X/L = 1$. As it closes the pressure wave travels across to the reservoir and reflects from it. With very little reorganiza-

```

BASIC WATERHAMMER PROGRAM
INTEGER I,N,J,U
DIMENSION V(20),VP(20),H(20),HP(20)
READ DATA
PRINT COMMENTS 1
PRINT RESULTS L,A,N,D,F,VU,TC,TMAX,J,G,M,H0
*001
*002
*003
*004
*005

STEADY STATE CALCULATIONS
DHF=F*L*V0*V0/(2.*G*D*N)
THROUGH B1, FOR I=0,1,1 .G. N
V(I)=V0
H(I)=H0+(N-I)*DHF
HP=H
C2=G/A
C4=V0*V0/(C2*H0)
TAU=1.
T=0.
DT=L/(A*N)
FF=F*DT/(2.*D)
U=0
PRINT COMMENT $0
HEADS AND VELOCITIES AT Y
ZENTH POINTS ALONG THE PIPES
PRINT COMMENT $0 TIME TAU X/L= 0. .1 .2 1.5
2 .3 .4 .5 .6 .7 .8 .9 1.5
PRINT FORMAT B21,T,TAU,H...H(N),V...V(N)
VECTOR VALUES B21=S1H0,F8.3,F5.3,S2.3H H=,11F8.2/S16.3H V=,11
2F8.2*5
I=I+DT
U=U+1
WHENEVER T .G. TMAX, TRANSFER TO B0
*006
*007
*008
*009
*010
*011
*012
*013
*014
*015
*016
*017
*018
*019
*020
*021
*022
*023
*024

COMPUTATION OF INTERIOR POINTS
THROUGH B4, FOR I=1,1,1 .E. N
VP(I)=.5*(V(I-1)+V(I+1))+C2*(H(I-1)-H(I+1))-FF
2*V(I)*.ABS.V(I)
HP(I)=.5*(H(I-1)+H(I+1))+V(I-1)-V(I+1)/C2
*025
*026
*027
*028

UPSTREAM BOUNDARY CONDITION
VP=V(I)+C2*(HP-H(I))-FF*V*.ABS.V
*029

DOWNSTREAM BOUNDARY CONDITION
C1=V(N-1)+C2*(H(N-1)-FF*V(N)*.ABS.V(N))
WHENEVER T .L. TC
TAU=(1.-T/TC) .P. M
OTHERWISE
TAU=0.
VP(N)=0.
HP(N)=C1/C2
TRANSFER TO B5
END OF CONDITIONAL
C3=TAU*TAU*C4
VP(N)=SQRT.(C3*C3/4.+C3*C1)-.5*C3
HELN=(C1-VP(N))/C2
THROUGH B6, FOR I=0,1,1 .G. N
V(I)=VP(I)
H(I)=HP(I)
WHENEVER U/J .E. U, TRANSFER TO B2
TRANSFER TO B3
END OF PROGRAM
*030
*031
*032
*033
*034
*035
*037
*038
*039
*040
*041
*042
*043
*044
*045
*046

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FIG. 2

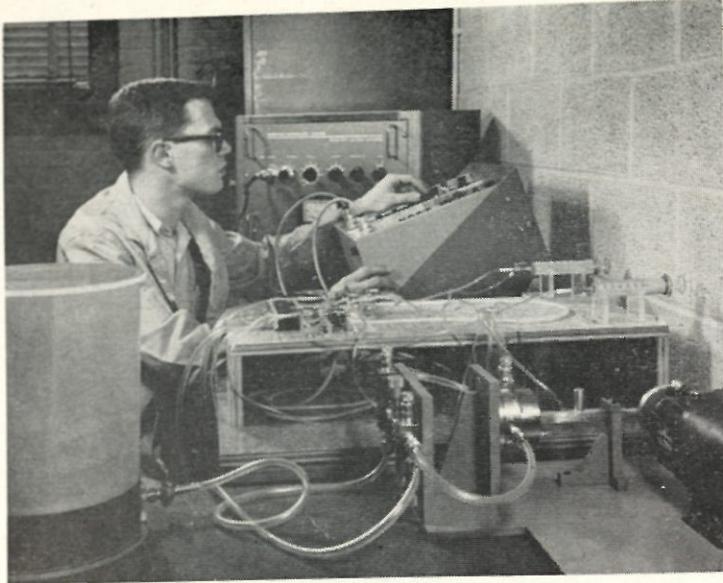


FIG. 5
LABORATORY AP-
PARATUS FOR MEAS-
URING TRANSIENT
FLOW OF HEART
PULSE THROUGH
LATEX TUBING.

tion this program may be applied to a variety of fluid transient problems in a single pipeline.

Figure 5 shows an experimental set up to study pulsatile flow through distensible tubing. A cam drives a piston to simulate the stroke output from the heart. This flow passes through check and bypass valves, then to a flow measuring probe (square-wave electromagnetic flow meter) then through pressure transducers to the flexible tubing. The set up is to study the role of energy dissipation in pulsatile flow.

Figure 6 is a portion of the solution by computer of pulsatile flow through a tapering flexible tube. The upstream (proximal) boundary condition gives the flow as a function of time which is taken from in vivo experiments. The downstream (distal) boundary condition is a terminal arterial bed relation in which the outflow is proportional to the head difference inside and distal from the end of the tube. Q is the flow (cc/sec), D the diameter (cm), V the velocity (cm/sec), and H the pressure head (cm Hg).

The goal of the arterial research project is to realistically simulate major portions of the arterial system so that specific detailed relations between cause and effect may be studied. Examples would be the effect of obstructions or stiffening of the arteries.

In the applications to water-hammer^{4, 5} several special situations have been examined by use of the high-speed digital computer and the method of characteristics. Studies of valve stroking have been made so

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that flow through a pipe from a reservoir may be brought to rest with controlled fluctuations in pressure and velocity. Water-hammer has also been studied for complex piping configurations such as series and parallel systems, and networks. Other applications are to transients set up by reciprocating pumps. Figure 7 shows the growth of a resonance condition in the suction line of a triplex pump.

The problems described could not

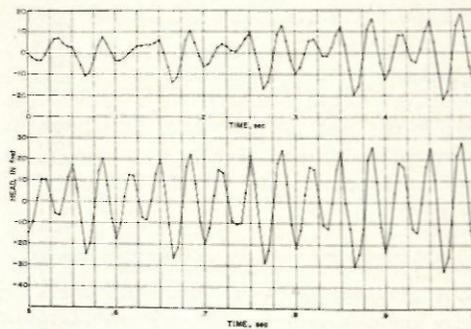


FIG. 7. COMPUTED RESULTS SHOWING RESONANCE CONDITION DEVELOPING ON SUCTION SIDE OF A TRIPLEX POWER PUMP.

GIVEN DATA FOR PULSATE FLOW THROUGH DISTENSIBLE TAPERED VESSEL													
$T = 5.000000$	$DPROX = 1.200000$	$DDIST = 1.000000$	$TPROX = .100000$										
$L = 25.000000$	$HR = 10.000000$	$HO = 15.000000$	$DAVE = 31.100000$										
$RHO = 1.000000$	$G = 980.000000$	$SG = 12.950000$	$F = .250000$										
$N = 20$	$DELT = 5.000000E-03$	$PTIME = .300000$	$P = .200$										
$KK = 2$	$NN = 2.200000$	$QM = 150.000000$											
PRESSURES(CM HG)		VELOCITIES(CM/SEC)		DIAMETERS(CM)		AND FLOW(CC/SEC)							
TIME	FLOW	X/	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
.000	.00	H=	13.492	13.469	13.407	13.458	13.552	13.588	13.533	13.450	13.412	13.429	13.359
		V=	.000	-.467	3.782	14.026	27.294	39.420	48.192	53.371	53.250	43.332	19.448
		D=	1.269	1.261	1.213	1.189	1.167	1.152	1.153	1.168	1.197	1.231	1.262
		Q=	.000	-.908	6.801	24.423	46.103	64.353	75.618	80.320	78.986	59.900	26.192
.010	69.89	H=	14.759	13.386	13.201	13.085	13.117	13.233	13.339	13.441	13.658	14.010	14.161
		V=	33.248	2.255	2.852	12.253	22.261	37.009	57.280	58.005	49.509	38.855	23.320
		D=	1.624	1.536	1.505	1.475	1.450	1.428	1.408	1.384	1.366	1.352	1.331
		Q=	69.889	4.191	10.393	22.123	40.028	59.303	73.537	78.317	72.515	52.782	32.443
.020	110.89	H=	15.299	14.449	13.055	12.843	12.756	12.858	13.112	13.483	13.962	14.398	14.500
		V=	51.923	34.247	8.086	12.737	19.809	29.479	39.012	42.457	37.316	28.569	24.700
		D=	1.659	1.583	1.497	1.466	1.437	1.415	1.398	1.385	1.377	1.366	1.351
		Q=	110.894	67.499	14.277	21.486	32.112	46.680	59.883	64.005	55.500	41.888	35.098
.030	131.97	H=	15.508	15.058	14.020	12.710	12.561	12.605	12.981	13.563	14.194	14.500	14.400
		V=	61.038	52.538	35.776	11.446	14.825	19.041	23.019	23.152	19.505	18.277	24.589
		D=	1.659	1.610	1.538	1.461	1.430	1.406	1.392	1.388	1.385	1.370	1.342
		Q=	131.967	107.066	66.466	19.179	23.738	29.590	35.044	35.089	29.402	28.952	34.770
.040	139.60	H=	15.569	15.331	14.727	13.664	12.529	12.404	12.997	13.634	14.154	14.300	14.189
		V=	64.336	59.875	54.011	34.109	8.686	6.615	2.436	-.781	1.549	10.008	23.441
		D=	1.662	1.623	1.568	1.497	1.428	1.405	1.394	1.391	1.384	1.363	1.332
		Q=	139.596	123.882	104.327	60.045	13.921	10.265	3.717	-1.184	2.331	14.597	32.682
.050	136.44	H=	15.555	15.446	15.070	14.533	13.599	12.850	13.235	13.599	13.817	13.846	13.743
		V=	63.855	61.728	60.413	51.081	23.836	-8.082	-17.458	-12.285	2.443	21.456	
		D=	1.661	1.629	1.584	1.533	1.468	1.415	1.402	1.390	1.371	1.346	1.316

FIG. 6

have been solved practically until recently. The mathematical methods were developed⁶ for supersonic flow studies in the 1940's, and the great amount of computation involved would have been prohibitive until the last few years.

Summary

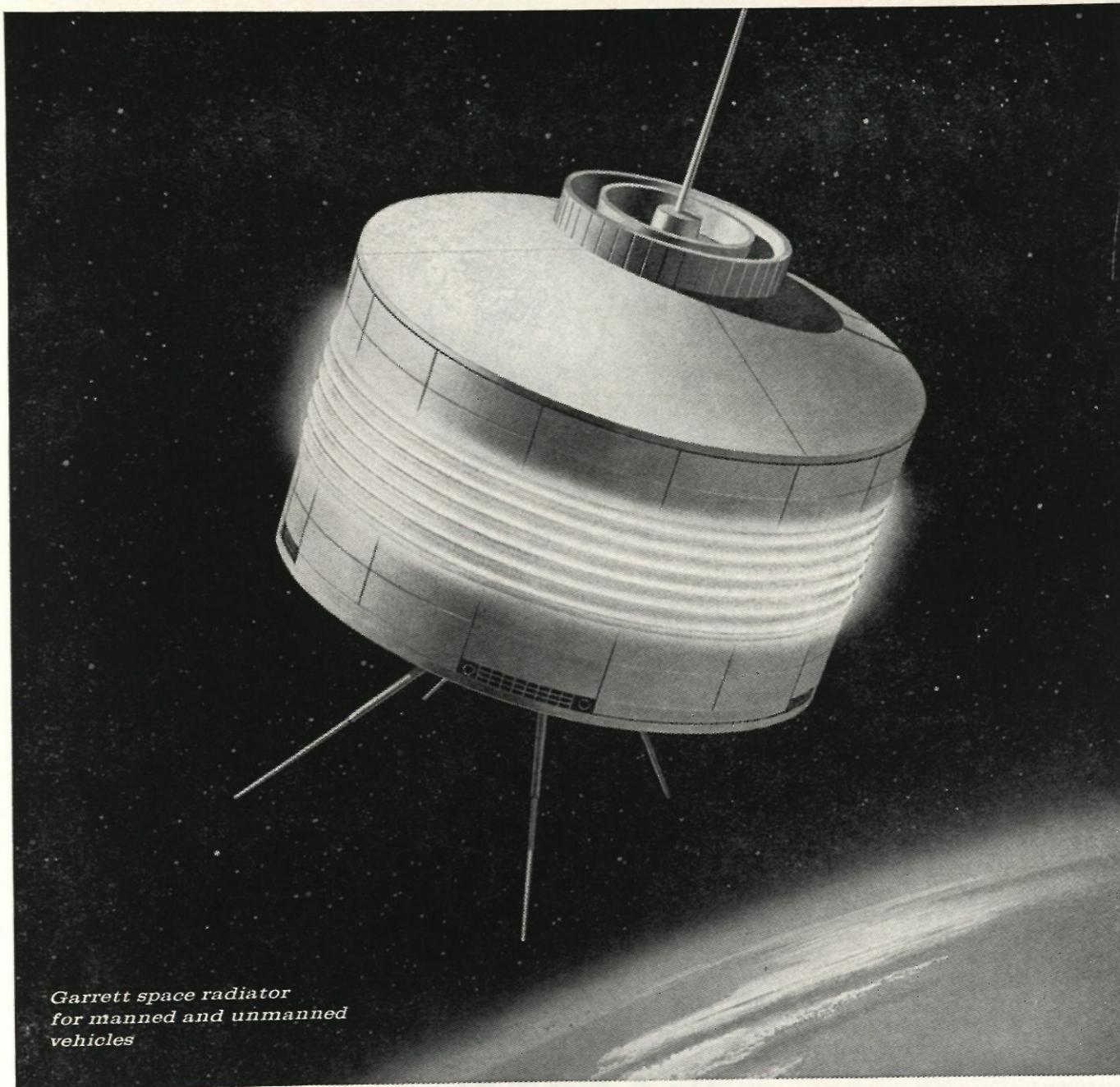
Progress is being made at such a high rate in all the engineering fields that it is essential that engineers take every opportunity to keep abreast of the new developments. Computing is one field that is most easily learned in college, and the University of Colorado has excellent facilities for use of computers in class work and in research.

Acknowledgments

The research on artery flow is supported by a grant from the National Institutes of Health for a project "Pulsatile Flow Through Distensible Tubes." The research in hydraulic transients is supported by a grant from the National Science Foundation.

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THE SCHROEDINGER

WAVE EQUATION

RON GOULD

As we are aware, classical physics at the turn of the century had conveniently sundered the description of natural phenomena into two distinct interpretations: field theory which embodied the wave nature of experimental occurrences, and particle theory which dealt with the Newtonian description of matter interactions. In dealing with interference, diffraction and polarization, the wave-nature suited the experiments of optical and electromagnetic processes, whereas, with atomic properties, the particle-nature was suitable, for it yielded distinct paths obeying the descriptions of Newtonian mechanics. Soon, however, experiments were detailed in which it could be illustrated that electrons, for example, exhibited a wave-nature as well as a classical particle-nature. Notably, it was electron diffraction and black-body radiation that served, not to force a wedge between the existing wave-particle theories, but to provide genesis for the quantum theory of matter that now unites the two interpretations.

Historically, the union between the

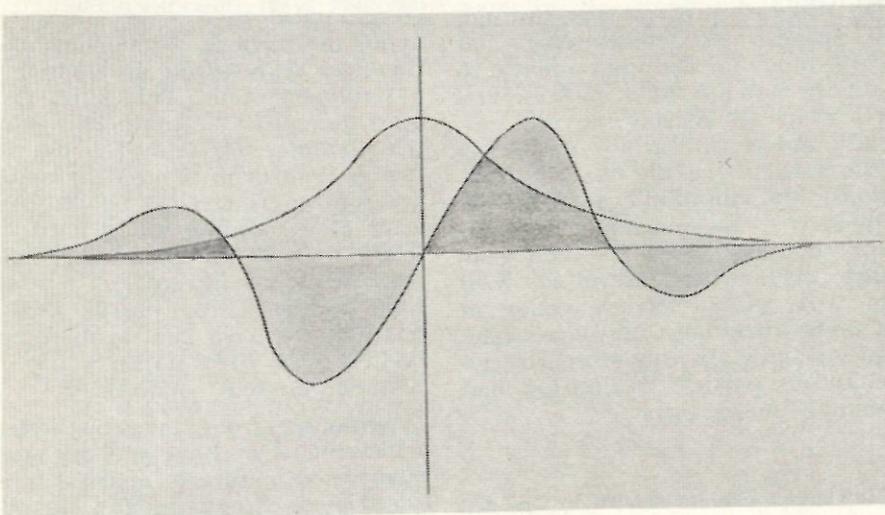
wave and particle nature of matter was achieved, though not necessarily appreciated, when Max Planck, in 1900, undertook the explanation of black-body radiation. His assumption, in opposition to the classical result, was that the energy (E) of an oscillator of natural frequency (f) was restricted to integral multiples of a constant times this natural frequency. Using this constant entity, Planck was able to match the empirically determined radiation curve to within experimental error.

The Planck action constant (h ; joule-sec) can now be shown to be the link between the microscopic and macroscopic worlds. On an atomic level the magnitudes of the properties involved are of the same order as that of the constant and the value for h (6.625×10^{-34} joule-sec) is certainly significant, whereas, macroscopically, h may generally be set equal to zero because of its relative exceedingly small magnitude, resulting in a wave picture for field quantities, and a particle picture for atomic constituents such as electrons. It is the detection of these units of energy in the

macroscopic sense, that is the barrier to the appreciation of them. Consider, for example, common springs or pendulua with periods of the order of one second. The product, hf , then retains its non-detectable magnitude of 10^{-34} joules and the allowed energy levels do indeed seem continuous under experimental conditions. Light waves, on the other hand, yield energy values that are detectable, hf being of the order 10^{-19} joules, and the basic energy units become empirically meaningful and observable.

These two examples imply the correspondence principle, wherein, when many quanta are involved, the laws of quantum mechanics must lead to the classical equations as an average result. Consider also the quantization of the gravitational field which, between participating planets, certainly leads to an average force.¹

The quantum nature of matter suggests, in fact demands that we yield to the interpretation of matter as having no intrinsic properties whatsoever. We may find this a difficult concept to grasp with only superficial investigation of the proposition. We must now think of matter as being something containing only incompletely defined potentialities that are developed when the object interacts with an appropriate system, by this system the one used to measure some characteristic of matter or merely the neighborhood of the matter itself. Specifically, the wave or particle nature of matter cannot be defined except to the extent that, under given experimental conditions the matter may lend itself to one or the other description as a result of the experimental conditions themselves. This may perhaps be thought of as continual transformations between the two conceptual descriptions which in themselves are not describable except statistically. In the classical limit,



however, these transformations are more meaningless because the wave-nature of matter becomes negligible.

It is carefully pointed out by most modern philosophers of science that these descriptions of matter cannot be considered to be a possible complex construction of even more obscure and undefined parts that arrange themselves into waves or particles as the situation demands. This would imply the existence of "hidden variables" as yet not included in the quantum mechanical theory and this possibility is not only inconsistent with the existing theory, but can be satisfactorily argued as nonconclusive. This is not to say that it is rigorously proved an impossibility, but the test for any theory, experimentation, does not lead one to anticipate these "hidden variables."

Once again the situation rests on the correspondence principle, the fact that, in the limit, the quantum properties must assume the classical properties. Quantum mechanically only the probability of an observable (position, momentum, et al) has significance, whereas, classically, observables are empirically available. The resolution of this is, of course, the fact that when viewed classically, the discontinuities are small and unobservable, and so many quantum processes take place that deviation from the actual result from the statistical average is too small to be detected.

Historical Development

Quite obviously the above discussion did not follow on the heels of Planck's black-body analysis. In the year 1913, however, the quantum theory took its initial steps with the achievements of the late Niels Bohr. At that time Bohr dealt with the so-called "old quantum theory of spectra" and defined the familiar Bohr atom concept. Because of this new theory's ready explanation of optical and Röntgen spectra, and the new light it threw on the structure of atoms, valency and the periodic system of elements, it was employed as a tool in physical research even though it was entirely alien to the contemporary foundations of physics. Bohr's fundamental postulates "were tolerated only on account of the extraordinary successes of the theory."²

Next appeared the "Bohr-Sommerfeld quantum condition," the quantization of the action variable, J , of classical mechanics, where $J = \int p dq$, and p represents the momentum conjugate of the space coordinate q . Significant was the quantization of angular momentum P_1 where the conjugate coordinate is ϕ and the in-

tegral is the phase integral of one period of ϕ ($P_1 h$).

$J = \int P_1 d\phi = 2\pi P_1$
where the integration is over the interval ($0 \leq \phi \leq 2\pi$), and the subsequent quantization of J ,
 $dJ = h = 2\pi dp_1$

and,

$$dp_1 = h/2\pi = h^*$$

or,

$$p_1 = Lh$$

where $L = 0, 1, 2, 3, \dots$

Bohr suggested that this quantization would apply for very small quantum numbers. (The actual expression, according to the "new quantum mechanics" is, however,

$$P_1 = h[L(L+1)]^{1/2}.$$

Here, then, we have seen how microscopic events were taking on a character of integral uniqueness.

de Broglie's Method

In the fall of 1924 an entirely different line of attack was published by Louis de Broglie. Guided by the Compton effect that had shown that the laws of mechanics held for collisions of electrons and photons, and that light transports linear momentum (p) as well as energy, de Broglie sought to establish a wavelength to be associated with matter. The fundamental postulate of "old quantum mechanics," as evidenced by Planck, held that the energy of a photon could be represented by the relation $E = hf$, whereas, the Einstein theory of relativity required that the energy of a particle at rest be mc^2 where m is the mass of the particle and c is the velocity of light. De Broglie proposed that the equality $hf = mc^2$ should therefore hold for material waves. However, as he immediately showed, the attempt to localize an oscillating particle of frequency f in some frame of reference violated the relativity theorem conditions. The fact that he did not abandon his pursuit at this contradiction led to the remarkable results of wave mechanics.

De Broglie's progress was through two propositions: phase-waves and wave-groups. To maintain the validity of the equality $hf = mc^2$ for any particle in all systems moving uniformly and rectilinearly with respect to the particle (i.e. the relativity conditions), the vibration event with the frequency f was extended over all space (not localized). He then associated the particle, traveling with velocity v , with a wave traveling in the same direction with phase velocity $u = c^2/v$. In this sense the instantaneous particle localization had absolutely no meaning.

* h is Planck's constant divided by 2π .—Ed.

This peculiarity was resolved by assigning not a unique frequency f , but a narrow band of frequencies ($f + df$) to the particle; that is, the construction of a wave-group or wave packet. Now the macroscopic observables associated with a particle could be ascribed to the characteristics of a wave packet that maximizes itself according to the laws of wave-kinematics and at the maximum carries the majority of the total energy. To associate, say the particle velocity with the wave group, it must be true that the group velocity equals the observed particle velocity. Hence

$$\frac{\partial \omega}{\partial k} = v_g = v = \frac{mv}{m} = \frac{p}{m}$$

where ω = the angular frequency of propagation, k = the packet propagation vector, $2\pi/\lambda$, v_g = the group velocity, v = the particle velocity and p = the particle momentum. From the fundamental relation, $E = hf = h\omega$, then

$$\frac{\partial \omega}{\partial k} = \frac{1}{h} \frac{\partial E}{\partial k};$$

yet, classically, $E = (1/2)mv^2 = (1/2)(p^2/m)$, so that

$$\frac{\partial \omega}{\partial k} = \frac{1}{2mh} \frac{\partial p^2}{\partial k} = \frac{p}{mh} \frac{\partial p}{\partial k}$$

This result must be equal to (p/m) as originally asserted. Therefore

$$\frac{1}{h} \frac{\partial p}{\partial k} = 1,$$

which, upon integration, yields the de Broglie relation.

$$p = hk = h(2\pi/\lambda) = h/\lambda$$

Although this derivation is not that of de Broglie, it is used here to illustrate the nature of the wave packet and its relation to the particle interpretation of matter.

De Broglie was also able to arrive at the Bohr-Sommerfeld condition of quantized angular momentum. He assumed that the allowed Bohr orbits corresponded to a wave propagated about the nucleus, a stationary wave therefore representing an electron in a stationary state. This wave, then must necessarily be continuous about the circumference defined by the particular Bohr orbit to meet the boundary conditions implied by the character of a standing wave. Then the relation $n\lambda = 2\pi r$ must surely hold, where n is an integer and r is the Bohr radius. Using the de Broglie relation, we have $2\pi r = nh/p$, and finally, $p_1 = rp = nh/2\pi = nh$, the Bohr-Sommerfeld condition.^{3,4}

Stemming from the quantization achievements of Bohr and the subsequent wave nature of material introduced by de Broglie in 1924, the phy-

sical foundations were reconstructed at the microscopic level and the postulates of quantum and wave mechanics were introduced during the next two years, 1925 and 1926. It is interesting to note that the structure of these two theories is radically different; that of quantum mechanics being the relationships between quantities that, in principle, are observable (i.e. position, momentum, et al) and that of wave mechanics, being the introduction of abstractions that are not observable (waves of unknown physical meaning in a multi-dimensional space.) Nevertheless, the conclusion drawn from these two theories are practically the same, the wave mechanics, though, lending themselves to a more amenable mathematical treatment.

The two theories mentioned above are, of course, those of Heisenberg (expanded by Born, Jordan and Dirac) and Schrödinger. Historically, the quantum mechanics (matrix mechanics) of Heisenberg preceded the wave mechanics of Schrödinger and will be given brief, but due mention here.

Matrix Approach

Heisenberg observed, generally, that the application of the macroscopic quantities, position, momentum, orbit, et al, to microscopic considerations of atomic theory was not meaningful in dealing with spectroscopy where energy levels and their differences accounted for the spectral lines. He reasoned that a new scheme, in view of Bohr's analysis, must replace the mechanics and kinematics describing macroscopic systems. This reasoning took the form of matrices describing quantum mechanical quantities, each quantity corresponding to an elementary process which had a unique frequency, intensity and polarization. The achievement of results then involved the calculation of momentum and position elements from their respective matrices, forming the Hamiltonian function (as a diagonal matrix, independent of time) which, in turn, becomes identical with the corresponding energy level. The unique frequency associated with two energy levels was then calculable. As here implied, the Hamiltonian of mechanics, $H(p,q)$, where p is the momentum and q is the position coordinate becomes a matrix which is a function of the momentum and coordinate matrices themselves. Except in rather simple cases the matrices involved yield a cumbersome number of equations and unknowns, a difficulty that is not encountered in the wave mechanic formulation of Schrödinger.

During the first month of 1926, Erwin Schrödinger, of the Physical

Institute of the University of Zürich (Switzerland) submitted the first of his papers dealing with "Quantization as a Problem of Proper Values" (Eigenvalues) in which he proposed to "show that the customary quantum conditions can be replaced by another postulate, in which the notion of 'whole numbers', merely as such, is not introduced . . . but arises in the same natural way as it does in the case of the node-numbers of a vibrating string. The new conception is capable of generalization, and strikes, I believe very deeply at the true nature of the quantum rules."⁵ The validity of the statement is now, of course, self evident.

Schrödinger, at a later date, continued, "My theory was inspired by L. de Broglie. . . . I did not at all suspect any relation to Heisenberg's theory at the beginning. I naturally knew about his theory, but was discouraged, if not repelled, by what appeared to me as very difficult methods of transcendental algebra, and by want of perspicuity."⁵

One might, at this point, deal with Schrödinger's succession of publications for the derivation of the wave equation and its interpretation. This would not, however, be necessarily informative in as much as he initially concerned himself with applications to specific problems. A reading of his publications should, on the other hand, generate more excitement, as it were, than will the unobtrusive derivation to follow.

Wave Equation

Consider a mon energetic beam of electrons of uniform intensity to be described by a plane wave in the form

$$\Psi'(q, t) = A \exp i \left(\frac{2\pi}{\lambda} q - \omega t \right)$$

where $2\pi/\lambda$ is recognized as the familiar propagation constant k , and q represents any of the spatial coordinates in this simple one dimensional case, and i represents the square root of minus one. The wave function Ψ' (Psi), however, has no meaning at this point. (Variables not identified are assumed familiar or have been previously noted above.) The application of the de Broglie relations ($E = hf = \omega h$; $\lambda = h/p$) yields

$$\Psi'(q, t) = A \exp \frac{i}{h} (pq - Et)$$

Differentiating once with respect to t and twice with respect to q yields the relations

$$E \Psi' = - \frac{h}{i} \frac{\partial \Psi'}{\partial t}$$

and

$$p^2 \Psi' = h^2 \frac{\partial^2 \Psi'}{\partial q^2}$$

which can be substituted into the expression for conservation of energy of electrons

$$E = (1/2) mv^2 = (1/2m) p^2$$

yielding the one dimensional Schrödinger wave equation

$$-\frac{h^2}{2m} \frac{\partial^2 \Psi'}{\partial q^2} = - \frac{h}{i} \frac{\partial \Psi'}{\partial t}$$

The extension of the one dimensional case of a plane wave traveling in any direction involves the replacement of p and q by the momentum vector p and direction vector r , and the realization that the spatial differentiation becomes the gradient operation as defined in the coordinate system under consideration. An external field may be added to the conservation equation: $E = (1/2m) p^2 + V(r)$; the final result being the time-dependent, general Schrödinger wave equation

$$-\frac{h^2}{2m} \text{del}^2 \Psi + V(r) \Psi = - \frac{h}{i} \frac{\partial \Psi}{\partial t}$$

where del^2 is understood to be the operator del dotted into del as interpreted in vector analysis.

From the wave equation in this manner, one can deduce one of the wave mechanic postulates, that of operator substitutions. Into the classical energy equation (Total Energy = Kinetic Energy + Potential Energy) the following dynamic variables are replaced by their respective quantum operators (or observables, following Dirac's notation):

q (position) remains q
 p (momentum) becomes $(h/i) (\partial/\partial q)$
 E (total energy) becomes $(-hi) (\partial/\partial t)$

and the wave function Ψ is inserted as the operand.⁶

Generally the wave equation is shortened to an equivalent form

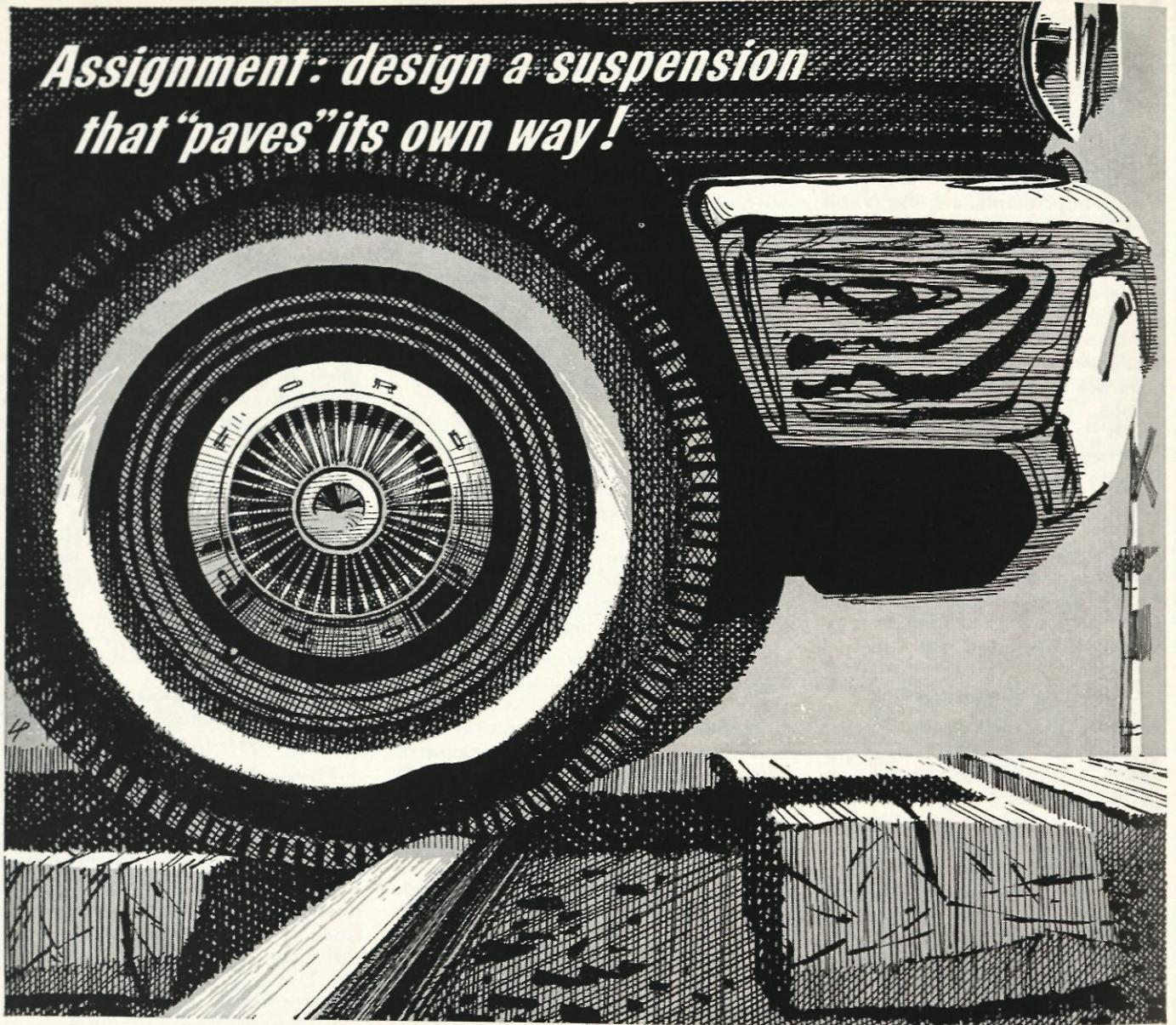
$$H\Psi = E\Psi', \text{ where } H = -\frac{h^2}{2m} \text{del}^2 + V(r)$$

and is the Hamiltonian function of the system, operating on Ψ' . Notice that the Hamiltonian may be interpreted as the energy expressed in terms of the momentum and position coordinates.

We are now left with the problem of giving significant, though not necessarily physical meaning to the Schrödinger wave function Ψ' . The operand in the more familiar wave equations we deal with does not present this problem of interpretation. For these, the "wave disturbance" might be transverse displacement, or

(Continued on page 48)

*Assignment: design a suspension
that "paves" its own way!*

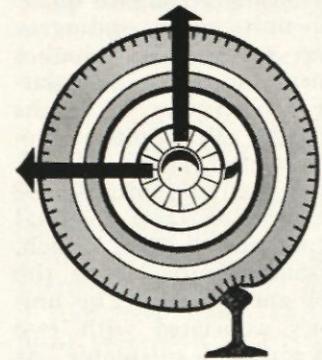


**Result: "Cushion Recoil" provides a
dramatically smoother ride
in 1963 Ford-built cars**

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**WHERE ENGINEERING LEADERSHIP
BRINGS YOU BETTER-BUILT CARS**

EXPERIMENTS IN ENGINEERING

LOWELL BROOKS

Many educators feel that one of the biggest problems facing an engineering student is that of making some sort of coherent "whole" out of his formal course work. Oftentimes it seems to the student that courses, even within his own field, are entirely unrelated. Furthermore, the connection between theory and practice seems, to him, to be nebulous—if it exists at all. Ideally it should be the function of his experimental courses to bridge this gap, and to help him realize the connection between the various disciplines that he is studying. However, many students feel that this is definitely not the case. To them, laboratories add up to an unending series of "cookbook" experiments followed by long lab reports. At the end of an interminable semester of lab, many an engineering student feels that about all he has accomplished is to gain a tiny bit of proficiency in the time honored art of executing busywork. This position, taken by some students, is clearly not entirely correct; on the other hand, it is not without merit.

With these thoughts in mind, several educators have set out to see if they could improve the laboratory curriculum at their schools. This article is a report on some of the ideas that were tried at various universities.

Probably the least radical approach to the problem was tried at the Case Institute of Technology during the fall semester of 1958. The results of the experiment were published in an article by Walter J. Fahey in the IRE, *Transactions of Education*, June, 1959. At Case, the primary emphasis was on the lab reports. Of the twelve experiments conducted, only the first and the last one had to be summarized by the student in a written report. For each of the other ten experiments, the student was required to keep a permanent bound notebook with data, calculations, graphs, etc. These notebooks were used for reference in an oral report given by the student at the next lab session. The reports averaged fifteen minutes in length and were conducted as reports organized and given by the student, rather than as an oral quiz by the instructor. During the last few minutes of the report, the instructor tried to obtain any neces-

sary clarification and to clear up any major misconceptions of the student.

Time limitations made it impossible for the instructor to hear every student every time, so sampling techniques were used in the hearing of the reports. Though the method of choosing the person to report was in a random fashion, individual cases became predictable as the semester progressed. A schedule of those expected to report was posted at the beginning of each session. Students were informed that failure to be prepared for an oral report would result in zero credit for that experiment.

Student's Point of View

The time required to prepare for an oral report varied from 50 to 100 per cent of that required for a written report. The biggest factors in reducing the time needed for preparing the report were: 1) the student no longer had to type a final draft, and 2) organization of thoughts in outline form replaced detailed explanation, much of which would be well-known fact but necessary for continuity of presentation. Therefore, a greater percentage of the time required for preparing the report could be spent in the actual understanding of the experiment.

It was also found that the oral

report provided an opportunity for questions which might not otherwise have been asked. Also, corrections were noted and understood, more often than was the case with written reports. One serious drawback with the oral report, however, occurred in conjunction with those experiments that required some synthesis or creative effort by the student. Unless a student was called on to give a report, he was never sure how fruitful his own efforts had been. Of course, he always had the privilege of taking the initiative and talking to the instructor about his efforts on any given experiment. In spite of this drawback, the student emphatically endorsed this type of experiment in preference to those which provided little latitude in procedure.

The student also felt that the written report was necessary and desirable, and since the instructor had fewer reports to grade, he was able to give more individualized attention to each report.

Taken together, the student response seemed to be one of active enthusiasm stemming from their estimate that they learned from two to four times as much per unit time expended on laboratory work, as compared with weekly written reports.



The value of direct communication was quite evident as it facilitated much better evaluation of the student's creative effort, and synthesis for the experiment. Also whatever understanding of the physical phenomena and of the related theoretical description was displayed by the students' oral report could be accepted as the student's own work. This was further evidenced by the fact that despite loss of credit, the few students found unprepared when called upon simply admitted the fact rather than attempting to "bluff" through an oral report.

There are, however, two things that the instructor must be very careful to do. One, is to see that the laboratory is in very good working order. Since most of the instructor's time in lab is occupied by hearing oral reports, he does not have time to "trouble-shoot" the student's apparatus. Secondly, he must be on guard at all times to keep from laying too much emphasis on the particular students' ability at public speaking. Though the ability to communicate is of prime importance, the instructor's job is to find out about the student's understanding of the experiment.

In total, it seemed that net effect of the experiment at Case was an improvement in the undergraduate lab involved.¹

Queen's University

A rather different approach was taken by W. G. Godden of Queen's University, Belfast, N. Ireland. Mr. Godden felt that one of the student's main problems is that of relating all the widely different courses he takes to the main purpose of his study—his own branch of engineering. For example, in the general field of structural engineering, it is quite likely that a student will study drawing, strength of materials, properties of materials, structural analysis, mathematics, and design without ever really understanding how these subjects are interrelated. Another problem with respect to civil engineering education is, it seems to Mr. Godden, that in the undergraduate training the student may not gain a knowledge of real as opposed to theoretical structural behavior. The student spends years analyzing idealized problems, and rarely does he face a real problem in which the idealized case is at best an approximation.

To combat this situation, Godden proposed an undergraduate "project" in structural engineering.

Purpose of the Project

The purpose of this project was threefold:

- (1) to encourage "inventiveness";
- (2) to show the inter-relation and application of the various branches of study to the general field of structural engineering;
- (3) to provide some insight into the complexities of real structural problems and structural behavior, and to develop engineering judgment.²

To meet the first purpose, the project must have as broad a scope as the student could handle. In particular, it was felt that the student need not be restricted to only those methods or projects which he could analyze exactly if he could justify a more advanced approach on theoretical grounds. In order to meet the second objective, the project had to be general to include as far as possible, all the various fields used by structural engineering. The third purpose presented no problem since any project which satisfied the first two aims was easily complex enough to introduce the student to the "real life."

It was found that the simplest project which would satisfy these aims was that of building a model structure. For example, the student would be given the profile of a gap—say the distance between banks at road level (e.g. six to eight feet.) He is also given a design load in pounds per square inch acting on the road surface, this could be continuous or discontinuous loading. He then has to design a bridge structure for this roadway with the given material and two given response criteria—a maximum vertical deflection of any point of the road surface, and a collapse factor for the complete structure. The minimum weight would also be given, not from a theoretical standpoint, but so that this factor would be kept in mind studying the overall geometry on the weight of the structure. It was found that the best material to use for these projects was silver spruce which could be bought in miniature rectangular sections, and was also a reasonably consistent material.

The student, then faced the general project and was forced to integrate his knowledge in order to carry it through to completion. He had to start from scratch, by determining the material properties he needed, then designing the structure. It sometimes happened that he had to test a partially completed section and hence had to design a test that would make the section react as it would in the finished structure. And in testing the finished structure, he had to design the test so that it would min-

imize the destruction when it was tested to the point of collapse.

It usually took two students working four to five hours a week, twelve weeks to finish a project. If, in the project, the student was being subjected to this kind of work for the first time, he was usually very slow in getting started. Naturally, he feels that he is wasting his time for the first couple of weeks. But during this time he is sharpening his faculties for analysis and synthesis. The seeming waste of time is a necessary evil and is well worth the effort.

The success of the project as a learning device is very dependent upon the instructor. He must be able to help the student when he gets stuck without actually giving him a pat answer to his problem. The most critical time for talking with the student about his project is after he has submitted his first report and when all aspects of the project can be discussed. The talk must take place promptly after the student has submitted his report in order that he may have sufficient time to review the discussion. If this is not the case, much of its value will be lost. This procedure obviously takes much instructor time, though not as much as might first be expected.

Most of the results of the projects have been gratifying in that they have fulfilled the purposes set out earlier. One unexpected result was that the student was often surprised that theory can be so meaningful. The close correlation between experimental and theoretical results seem to be something he did not expect. And it gives him confidence in theoretical work as well as some caution when applying these results. It was noted that when a student becomes involved in a project that is meaningful to him and that gives him scope for imagination and opportunity to use all of his knowledge, it is the sort of work in which he will take a genuine interest, and from which he will learn a great deal, and in which he will take pride in presenting in the form of a well prepared report.³

Syracuse University

The most radical change noted in laboratory curriculum, was made by Syracuse University. In 1959 all laboratories previously associated with required E. E. courses were dropped. In their stead, all required laboratory was incorporated into three courses, each carrying three credit hours. With the laboratory removed from its traditionally dependent role, a wider choice of technical topics was

(Continued on page 47)

The New Astronomy

A collection of articles by various authors published by Simon and Schuster, New York, 242 pp., \$1.45, paperback, 1955.

The New Astronomy is a collection of articles previously published in "The Scientific American." The articles are written in non-technical English and include many helpful pictures for the interested layman. The book is divided into three general categories: the universe, our galaxy, and new methods of observation. These articles do a wonderful job of linking the astronomy of the past with modern theory and its applications.

In the first article, George Gamow discusses the subject of Cosmology (the attempt of man to relate observed facts of the universe with known physical laws and thus piece together a consistent picture of the structure in space and time of the universe). One theory of its origin is that it began as expanding photons which gave way to solid particles of matter. Slowly the solid particles formed more complex nuclei which (after 750 million years) broke into galaxies and condensed into stars and planets. Today, with observation done at Mount Palomar, the earth is believed to be five billion years old.

Other observations and experiments have led to the idea of the fourth dimension and of space being curved "like a saddle in the shape of a negative sphere" which is expanding. (This curvature has associated with it, due to the presence of matter, a turbulence which is now being studied under the new subject of magneto-hydrodynamics.) Albert Einstein theorized much of these ideas, but he had the aid of earlier mathematicians such as Gauss and Riemann who believed in "curved space."

The study of our own galaxy with emphasis on our solar system make up a major portion of this book. There is a section discussing the birth and death of stars with relation to their size, color, and brightness. Fred L. Whipple explains the origin of the earth with his "dust cloud" hypothesis. The mass of this "dust" has been calculated by Jan Oort of The Netherlands, and even though the small "dust" particles are spread so thinly as to be less dense than the greatest vacuum on earth, the force of attraction between particles helped form larger particles.

Ever since man believed the earth was on the back of an elephant while the elephant stood on a turtle, man has been adding these theories on the origin of the universe. But today, with the aid of two most important instruments, the radio tele-

BOOK REVIEWS

ELLEN CARR

scope and the photocell, (which are discussed in the last section of this book) many of these theories will be either discarded or confirmed.

It is an extremely interesting and readable book.

Grateful acknowledgment is hereby made to Sandy Pyle, a sophomore in Aeronautical Engineering, for the contents of this review.

Electronic Rectification

By F. G. Spreadbury, 428 pp., D. Van Nostrand Co., Inc., New Jersey, 1963, \$10.00.

Due to the increasing and continuous demand for direct current (d.c.) the conversion of a.c. to d.c. by static devices is becoming increasingly important.

This subject is dealt with by Mr. Spreadbury in *Electronic Rectification*, a book based on fifteen years experience in the design and construction of rectifier installations.

The first chapter discusses the principles of rectification. Chapters Two through Six deal respectively with Solid-State Rectifiers, Vacuum-Tube Rectifiers, Gas and Vapour-Filled Rectifiers, Mercury-Pool Rectifiers. (Although the theory of Solid-State Rectifiers is relatively advanced only for silicon and germanium, this lack is no impediment to the practical applications of other solid-state rectifiers; these applications are fully discussed.)

Chapter Six deals with rectifier circuits. After stating some simplifying assumptions, the author proceeds from single-phase circuits to bridge circuits to star circuits and to higher phase circuits, to mention some of those discussed.

Chapter Seven is on rectifier operation and control and discusses the types of control which best fit each type of rectifier, as well as operational problems such as cathode heating, overload and fault, and fuse failure.

Chapters Eight and Nine deal with rectifier applications and rectifier design considerations and construction.

Each chapter contains its own bibliography, making cross-reference conveniently easier. The book is up-to-date and authoritative—valuable for anyone doing work in this field.

The Analysis of Sensations

By Ernest Mach, 371 pp., Dover Publications, Inc., 1959, \$1.75, paperback edition.

The name of Ernest Mach is familiar to all students of science and engineering. He is also well known by students of human thought as the initiator of the study of the philosophy of science. Albert Einstein writes, "I see Mach's greatness in his incorruptible skepticism and independence . . ." The idea has also been suggested that had physicists been discussing the constancy of the speed of light during Mach's time, he would have formulated the theory of relativity.

What was obvious to others was to him a subject for thought, experimentation, and observation; this characteristic is closely related to his faculty for discovering something new and startling in what had hitherto seemed exhausted. (It is interesting to note that A. C. Bradley attributes a similar characteristic to Shakespeare's Hamlet.)

Although this book is mainly interesting from a historical viewpoint—that of showing what the brilliant thinkers of the intellectually active Nineteenth Century were discussing and pondering—it also contains some thoughts relative to current problems. For example, Mach believed that the confusion resulting from transferring preconceived opinions from physics to psychology was quite serious.

He also believed that the fear of ghosts is the true mother of all religions, although he gives no basis for this belief, other than a few observations which indicate that this fear exists innately (i.e. his young child avoided the coal shuttle, which resembled a pair of gaping jaws, at night).

He considered metaphysics out-date as far as philosophy was concerned: "... advocates of the old metaphysical conceptions which the philosophers have already largely abandoned.

He felt that there was no real distinction to be made between a teleological "why" and a causal "why." (Teleologically, a hawk-moth spins a cocoon with a bristly flap opening outwards because such a cocoon is best suited for preserving the caterpillar's existence. Causality asks what impels him to do this.) Mach felt that the idea of survival of the fittest" answered both these "whys."

Mach discusses in some detail and with psychological inferences the sensations of the eye. For example, he discusses the similarities and differences of a geometrical and a psychological space. Geometrically, a square resting on its side and one resting on its corner are the same; psychologically they are different.

According to Mach, "Memory and Association are the fundamentals required of a developed psychical life." He discusses several theories, current in his time, on the memory process. He discusses the questions of animal sensations and even of inorganic sensations; concluding that the last ques-

tion has no meaning since behavior of inorganic substances cannot be explained by assuming that they have sensations.

He also felt that there exists an inertial sensation which could, for example, reverse in the mind the order of two nearly simultaneous events, as compared to the order in which they actually occur.

This book contains some interesting and appealing ideas, and I feel that much food for thought can be gained from it.

Mechanical Springs

Second Edition, by A. M. Wahl, 317 pp., McGraw-Hill, \$12.75, 1963.

Mechanical Springs is a book designed to bring together as much as possible of the large amount of material available on mechanical spring design and spring materials. The material selected is both theoretical and practical. The basic theories underlying the design of a wide variety of types of mechanical springs are treated extensively. These types include coned-disk, torsion, flat, leaf, ring, volute, torsion-bar and rubber springs; primary emphasis is on the helical compression or tension spring, since it is the most widely used type.

One reason for the second edition was the need to cover important advances in the field of mechanical springs. Mr. Wahl discusses such developments as buckling and lateral loading in helical springs, plastic flow effects due to presetting of helical springs, effects of bar curvature for helical springs under fatigue loading, elevated temperature effects, expansion of coils of helical springs, and effects of pitch angle.

The book will be especially useful for spring designers, stress analysts, and engineers employed in this field. Numerous charts, tables, and curves are given throughout the book for the convenience of the designer. The topics mentioned above should be of interest to stress analysts and engineers.

Mr. Wahl is now Advisory Engineer in the Research and Development Center of the Westinghouse Electric Corporation in Pittsburgh, Pennsylvania. A graduate of Iowa State University and the University of Pittsburgh, Mr. Wahl has been with Westinghouse for the past thirty-six years and has written approximately seventy technical articles. This experience indicates that his book would be extremely valuable from a practical standpoint.



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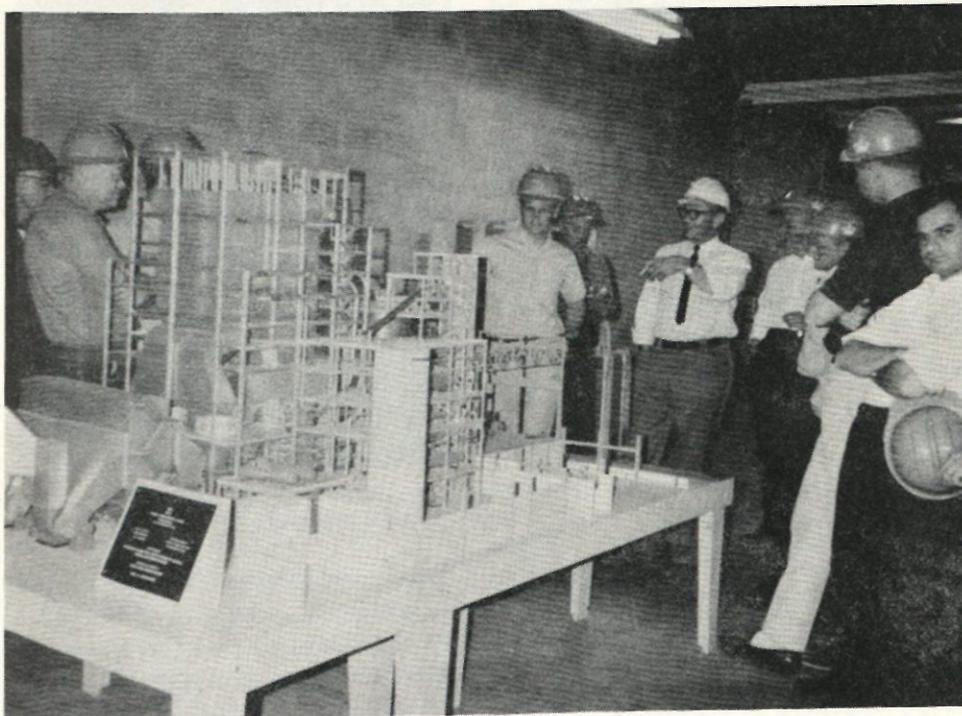
E-DAYS COMBINES

FUN

AS CAN BE SEEN BY THE FACES
OF OUR STUDENTS ENGAGED IN A
TUG-O-WAR CONTEST AT THE
ANNUAL PICNIC.



The College of Engineering's 1963 ENGINEERS DAYS



AND THE
LEARNING

PROCESS, WITH THE VARIOUS
SEMINARS SHOWN HERE, IS THE
CIVIL ENGINEERS FIELD TRIP.

CONVOCATION

Every year in May, engineering students take time from their respective studies to celebrate Engineers' Days. During this time, the engineering students honor outstanding members of their college, attend seminars, and relax at the luncheon, ball and picnic.

Jerry Cashen, President of the Associated Engineering Students, opened the convocation at Macky Auditorium on Friday, May 3, and quickly turned the program over to Dean Peters and Dean Hutchinson. Together they announced and presented the awards and scholarships to outstanding students. Associate Professor Herbert Johnson was awarded the Associated Engineering Students Faculty Appreciation Award for outstanding service to the student body. Professor Leo C. Novak was awarded the Civil Engineering Faculty Appreciation Award for his work with the Civil Engineering student organizations. Keys were awarded to the newly elected AES officers for '63-'64—Lynn Kramer, Jean Dexheimer, Dean Peed, and Ross Fraker. The incoming editor and business manager of the *Colorado Engineer*, Larry Huston and Ross Fraker, also received keys. The highlight of the awards program was the presentation of the Colorado Engineers Council Silver Medal for the Outstanding Senior Engineer. Mr. John E. Martin, President of the Council, presented the award to Frank Cazier.



KEYNOTE SPEAKER DR. WILLIAM EVERITT

Dr. William L. Everitt, Dean of the College of Engineering at the University of Illinois, was the keynote speaker for Engineers Days. Dr. Everitt received his B.S. in Electrical Engineering from Cornell University in 1922, his M.S. from the University of Michigan in 1926, and his Ph.D. from Ohio State in 1933. He taught



FRANK CAZIER RECEIVING OUTSTANDING SENIOR ENGINEER AWARD FROM MR. JOHN E. MARTIN.

at Ohio State until 1944 when he went to the University of Illinois, where he became Dean in 1949. Dr. Everitt has served on many government committees and is presently on the Army Scientific Advisory Panel. He has numerous articles and publications to his credit and is a member of several technical societies.

Dr. Everitt pointed out that engineering is a learning profession, which requires constant study to keep abreast of current knowledge. He said that for this reason the objective of the engineering student should not be simply knowledge, but wisdom and understanding. The student should gain confidence in his ability to learn so that he will be able to learn for himself the things which are not taught in college.

Dr. Everitt then went into the difference between open and closed controls. Open controls give a single command to start a process and then have no further effect upon it. Closed controls employ feedback to make corrections during the process. For instance, as an animal walks it uses its eyes to guide itself. Dr. Everitt said that this feedback process, often found in biological mechanisms, can be studied and put to use in computer development.

The moral of John Steinbeck's play, *Of Mice and Men*, is that power without control is dangerous. Dr. Everitt cited this play as an example of why we must apply feedback to life in general. He stated that too often we go through life with open controls and do not try to understand those around us. He pointed out that American engineers in their work all over the world have an excellent chance to use feedback to develop an appreciative understanding of other people and their needs.

SEMINARS

A. MATH.

The Society for Industrial and Applied Mathematics sponsored Dr. Paul Hultquist of the University of Colorado who presented, "Mathematical Problems of Satellites." One of the main problems discussed was that of release of the satellite from the rocket. Dr. Hultquist gave the derivation of a formula which essentially expressed the type of orbit to be expected as a function of the energy given to the satellite at the moment of release. As the satellite is carried from the earth it gains in potential energy. If, at the moment of release, the kinetic energy given the satellite in a tangential direction to the proposed orbit, is less than the potential energy it has acquired, the orbit will be elliptical. If the kinetic energy equals the potential energy, the orbit will be parabolic, and if the kinetic energy is greater than the potential energy, the orbit will be hyperbolic. Determining the correct amount of energy needed to maintain the proper orbit is a mathematical problem.

Another problem results because the earth is not spherical but spheroidal in shape with more mass distributed around its equator. Therefore, attraction of the earth distorts the satellite's path near the equator causing the plane of the orbit to rotate 10° per day toward the west.



JIMMY LEEDS ENTERTAINING AT THE LUNCHEON.

These problems confront mathematicians, everyday, and although most cannot be exactly solved, by coordinating theory and observation, suitable solutions have been found.

CHEM. ENG.

The American Institute of Chemical Engineers sponsored Mr. John O'Brien of Continental Oil Company who presented a talk on "Technical and Social Problems of Automation." It was brought out that the petroleum and chemical industries have had a certain degree of automation for many years, with many technical problems but few social problems as a result. One technical problem is the degree of automation actually needed to produce a more efficient but less expensive system. For instance, the chemical industries generally have more automation than the petroleum industries because the raw materials of chemical industries cost more than the raw materials of the petroleum industries. Therefore any decrease in the cost of the raw materials, which accompanies automation, would result in a larger overall gain for the chemical industries than for the petroleum industries. The machinery necessary for automation is expensive and the gain in profit must offset the loss in automation expense which is not always the case with petroleum industries.

It was also mentioned that the social problem of less work for people as a result of automation is perhaps not as serious as is sometimes thought. No machines are able to work continuously and companies must have employees capable of taking over the work of the machines when the automatic system breaks down.

CIVIL ENG.

Mr. Herbert Haymaker, Vice-President of the Falcon Airmaps sponsored by the American Society of Civil Engineers, spoke on the history of the camera and photogrammetry. He defined photogrammetry as the art and science of using photography to make measurements. Some examples of this are building measurement for historic purposes, x-ray measurements, and topographic mapping. The most extensive use of photogrammetry is aerial surveying for maps. After the seminar, the CE's went to Valmont Power Plant for a tour of the new plant facilities now under construction.

ELEC. ENG.

Mr. Edward Ramaley of the Martin Marietta Corp. discussed "The Role of the Engineer in Manufacturing." In particular, Mr. Ramaley spoke at length on the working relationship desired between the engineer and shop personnel.

S.W.E.

An open discussion on "Engineering Education" was directed by a panel composed of professors Johnson, Timmerhaus, and Rautenstrauss. Topics discussed included the engineering curriculum, recent trends in engineering enrollments, student motivation, and the role of high school and college counselors in guiding prospective engineers.

AERO. ENG.

Mr. Allen Pope, director of a high-altitude rocket research team at the Sandia Corp., spoke on "Experience with 500 Research Rockets." Mr. Pope highlighted two projects undertaken by his team. The first project was that of determining wind velocities between 200,000 and 300,000 feet over an area of northern Nevada. The project's objectives were achieved through the use of a two-stage solid

propellant rocket which ejected aluminum chaff at the desired altitude. The motion of the chaff, recorded by elaborate radar tracking equipment, provided a means for determining the wind velocities. The second project was designed to facilitate development of a barometric fusing system. Although Mr. Pope did not elaborate on this system, he did discuss the rocket employed. The operation of this rocket was unique in that the second stage was ignited while in its earth-bound freefall. This method allowed the vehicle to attain Mach 5 velocity at impact.

Mr. Pope boasted that his team has attained a level of success unexcelled by any other group in the country. Over 95% of the more than 500 launchings attempted have been unqualified successes. In addition, not one member of the team has yet sustained a serious injury.



DEAN HUTCHINSON AND QUEEN LINDA LAKE.

E-DAYS BALL

The Dave Etheridge Orchestra provided a balanced program of very enjoyable and danceable music for the Ball. The Glen Miller Ballroom was comfortably filled by 9:30 Friday evening. At 10:30 the candidates for E-Days Queen were presented. Dean Hutchinson had the enviable honor of crowning Linda Lake Queen. Miss Lake's attendants were Linda DeBroeck, Judy Lesser, Frances Field, and Diana Lapp. The queen and her court led the dancing after the crowning.



LUNCH TIME ON THE GRASS.



BEASTLY BLAKE, THE BRAUNY BRASIER AND THE PURPLE SCREW.

PICNIC

The E-Days Picnic at Chautauqua Park on Saturday brought the festivities to a close. After a long wait in the chow-line and a plentiful lunch, everyone gathered around the department teams to see who would wear egg for the rest of the day. After this first messy event, the departments competed for top honors in the tug-of-war, the 4-legged race, the bat race, and the double-wheelbarrow race. A box score of the results appears at the end of the article. The results of the "Meanest Professor Contest," after a vigorous campaign highlighted by several demonstrations, colorful advertising, a television appearance and many jeers, were announced. Assistant Professor John H. Blake was awarded the Purple Screw trophy and Assistant Professor Robert Christopher, who was voted the least mean of all the professors, was awarded the Green Weenie Trophy. The contestants were Beastly Blake the Brawny Bruiser, Fearsome Pearson the Unprincipled Paranoid, Thundering Thoman the Bad Luck Omen, Matrix Meyers the Morbid Mystic, and Cruel Cranky Christopher the Crushing Crucifer. Spectators declared the "Miss Most Perfect Body" contest the highlight of the afternoon. After considerable debate, the judges, who were men of long experience, declared Carol Hirsch the winner. The contestants for that event judged Jody Javernick the "Most Kissable Engineer." After these special events, the trophy for field events was awarded to the Electrical Engineers, who had tied the Civil Engineers in total points, but had won more first places. The Civils plan to spy on EE labs to prevent any practicing for next year's events.

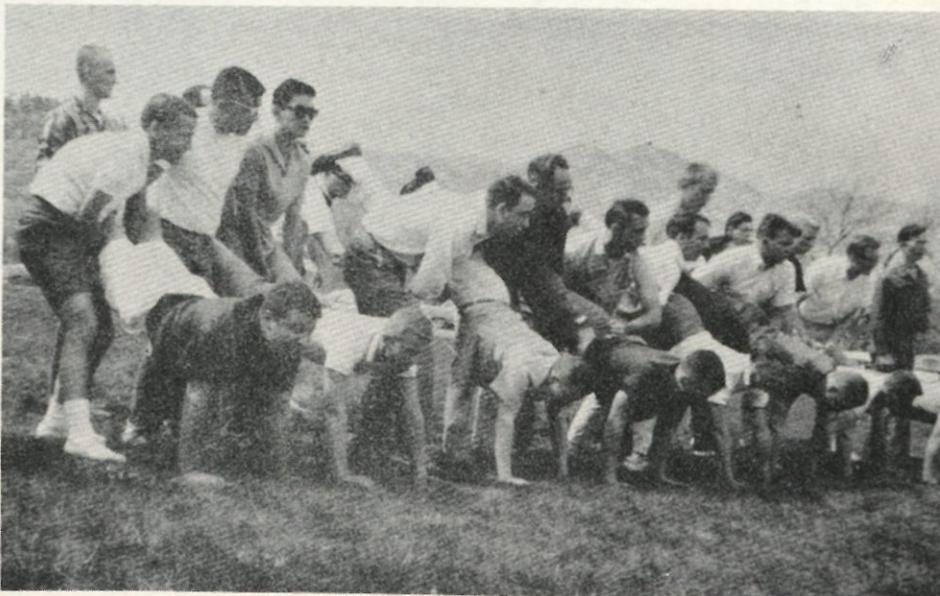


LEFT: AIN'T NOBODY TOLD ME THREE LEGS ARE BETTER THAN TWO.



RIGHT: HAPPINESS IS A KISS FROM MISS PERFECT BODY CONTESTANT.

ON YOUR MARK; GET SET; WHEEL!!



	1st	2nd	3rd
Egg Toss	EE	CE	Chem E
Tug-of-War	EE	CE	Aero E
Wheelbar. Race	CE	EE	Aero E
Bat Race	CE	Aero E	ME
4-legged Race	EE	ME	CE

DEAN'S PAGE

DEAN PETERS

As our 1962-63 school year draws to a close, I want to wish all of you who will be graduating the best of success in your future careers. I hope you will always look back on your days at the University of Colorado with pleasure, and I hope you will always be ready to announce with pride that you are Engineering alumni of the University of Colorado.

This has been a good year for us in the College of Engineering. Our faculty has been active in expanding its research activities and in developing new teaching programs. I have been particularly pleased with the additional emphasis we have placed on acquiring up-to-date and complete Library holdings and in bringing in outstanding technical speakers to our College from all over the country. Our faculty has been unusually active in attending technical conferences all over the United States while simultaneously developing plans for high-level types of conferences to be held here on our campus. We have been having excellent success in attracting outstanding men to join our faculty, and I will have a very significant report to give on the new additions to our faculty in the Fall issue of the **COLORADO ENGINEER**.

Two of our faculty members, Professor Frank Eastom of our Electrical Engineering Department and Mr. Vernon Parker of our Engineering Graphics and Machine Design Department, will be retiring at the end of this school year. These men have done a fine job for us here at the

University for many years, and we wish them the best of success and happiness as they retire from active service at our University. We, also, wish the best of success to Professor Willis Worcester of our Electrical Engineering Department who will become Dean of Engineering at Virginia Polytechnic Institute this summer.

Another "first" for our College this year is the closed circuit television course being offered by Dean Hutchinson in Applied Mathematics. Dean Hutchinson, as we all expected, has become a real television star and is doing a fine job in teaching the course. He appears on camera in Boulder with the class being broadcast to 11 students in Boulder and 46 students at the Denver Extension Center. An audio system enables students to ask questions and take part in discussions.

The television course being offered at the Denver Extension Center is part of our expanding program at the Center to serve the Denver area with Engineering instruction on both the undergraduate and graduate levels. At the present time, approximately 1350 students are enrolled in the Engineering program at the Denver Extension Center, including 960 undergraduates and 390 graduates. Just as on our Boulder campus, the teaching program in Engineering at the Denver Extension Center is continually being improved. For example, the Center has recently obtained the latest in desk-model cal-



culating equipment and will offer an undergraduate course in numerical methods in addition to the existing graduate course. We have acquired for the Center a small analog computer and will offer a course in analog computation and simulation. Currently, master's degree work may be completed in the Engineering Division of the Denver Center in Aeronautical Engineering, Applied Mathematics, Civil Engineering, Electrical Engineering, and Mechanical Engineering. Plans are under way to permit completion of the undergraduate Engineering degree requirement at the Denver Center with the laboratory courses being taken on the Boulder campus by means of a commuting arrangement. A Committee, under the Co-chairmanship of Dean Hutchinson and Professor Rautenstrauss, are working on plans to enlarge our Engineering program in Denver in an effort to offer a more-complete program for the local students and to meet the educational needs of an urban community in which many thriving technically oriented industries exist.

With our Engineers' Days being held on May 3 and 4, we have taken an opportunity to recognize the accomplishments of our students and review the advances we have made in our College during the past year. As you return to your home or new positions for the coming summer, I hope you will carry with you some of the enthusiasm all of us on the faculty have for the developments occurring in our College of Engineering. We sincerely hope you will pass on to your family and friends your feelings as to the progress we are making in Engineering at the University of Colorado.





Isometric Exercise For The Engineer

As we all know, the old-fashioned concept that exercise and perspiration must go together has been out-moded by the revolutionary discovery of the principles of isometric exercise or, "How to Do Nothing while Really Trying." These principles say that a man can put in an entire day's workout while riding home on the streetcar and nobody will even notice (as long as he doesn't turn blue). All that one has to do is push, pull, or squeeze something that won't push, pull, nor squeeze; keep it up until fatigue sets in and presto—with literally no sweat—bigger, better biceps.

The potential for isometric exercise (I.E.) is vast indeed. Perhaps some day I.E. will rank right along with the great inventions of mankind such as the steam engine, T.V. dinners, and antacid pills. New applications of the principles of I.E. are appearing every day. Right now, for instance, you can buy a half of a golf club with a chain on one end for attaching to the wall, by assuming different positions of the golf swing so that the chain is held taught one builds power, grace, and accuracy into his golf game.

As yet, however, no devices or exercises have been designed specifically for the engineer. This oversight is probably not intentional on the part of physical educators and should only

be attributed to a lack of appreciation of what isometric exercise fully implies. (This will be explained further on in more detail.) Let us consider I.E. from the point of view of the needs of the engineer. Of course the beauty of this system lies in its simplicity. The first device that probably comes to every engineer's mind would be a slide-rule that doesn't slip. This will enable the engineer to strengthen his thumb and index finger to at least three decimal places. A little more expensive but still reasonable device would be a test panel covered with knobs, switches, buttons, and levers. It is essential, of course, that nothing on the panel be able to move or the whole purpose is defeated. Isometric exercise is founded on the principle of no motion.

Besides the obvious advantage of these exercises in strengthening the engineer in his job the vaster implications should not be overlooked. Consider, for example, the engineer who works in an office and merely pushes a pencil, dials a telephone, or pushes intercom buttons all day. Since the dawn of the industrial revolution this has been considered sedentary type work—lacking sufficient body movement. These men have had to supplement their lives with several hours of moderate-to-heavy exercise

each week just to stay healthy. The principles of I.E. now clearly show that the problem has been approached just backwards. It is now clear that the trouble has been too much movement. The pencils, paper, and telephone dials all move much too easily.

Some day, perhaps, corporations will realize this, start installing their own inexpensive, highly specialized gymnasiums for their employees. In the meantime though, the ambitious engineer can do fairly well for himself by taking his lunch hour in a bank or post office where they have ball-point pens chained to the wall.

Many advances in education have been made lately. Some claim to cut learning time in half. However, as yet no applications of I.E. have been devised for the mind. Thinking is perhaps not clearly enough defined yet so that one can tell exactly what is meant by mental effort without mental activity. The field of psychology is relatively young yet and we must be patient. As a final thought on this subject for future research, the yoga principles of deep concentration on absolutely nothing, look extremely promising.

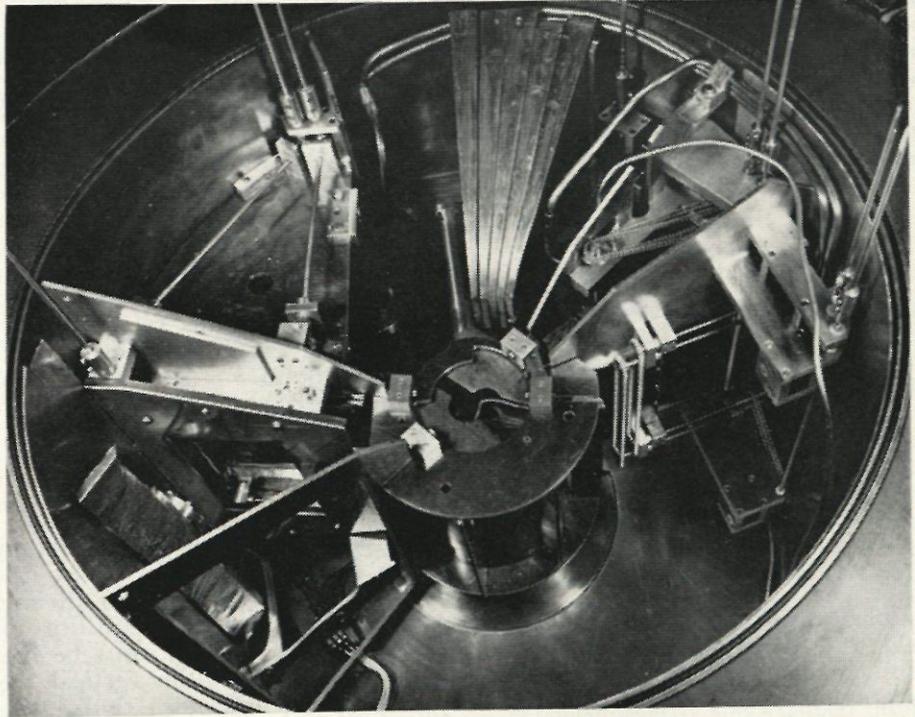
—NICHOLAS STILWELL.

THE DOUBLE-FOCUSING

A double-focusing, beta-ray spectrometer has just been completed in the basement of the Physics building, mainly as a result of the work of Prof. A. A. Bartlett of the Department of Physics of the University. Throughout the development of the spectrometer many graduate students contributed to the project. The work was supported by the National Science Foundation and by the Council on Research and Creative Work of the University of Colorado.

A beta-ray spectrometer measures the momentum of high speed electrons. When a radioactive material decays, it emits beta-rays and gamma-rays. Beta-rays are electrons, which may be studied directly in the spectrometer, while gamma-rays are electromagnetic radiation, which cannot be directly studied. However, its energy and intensity can be found by converting some of this energy into kinetic energy of an electron. This is done by projecting the gamma-rays against a thin sheet of a heavy metal like uranium. The gamma radiation interacts with the atoms of the heavy metal, resulting in the emission of electrons. The energy of the gamma-ray (E_1) can be found by: $KE(\text{electron}) = E_1 - \phi$; where ϕ is the binding energy (the work function of the Einstein photoelectric equation) of the electron in the atom of that particular heavy metal. The thin metal sheet is called the converter.

The spectrometer collects some of the electrons, either those directly from the source or from the converter, and focuses them at some point. The ideal case would be to collect all the emitted electrons; however, this is impossible, so one usually settles for a percent of the total electrons emitted into the solid angle which the spectrometer is able to focus. That is, the only electrons that are focused to an image are those in a cone of some solid angle: in the



BETA-RAY SPECTROMETER

WARREN WILSON

Warren Wilson is a junior in Engineering Physics. He is a member of Chessman, the men's residence halls honorary, works as librarian in Nichols Hall, and plans to do graduate work in Physics.

University of Colorado's this is 5% of 4π steradians.

Magnetic spectrometers* are of two basic types: those in which the magnetic field is perpendicular to the plane of motion of the electron, called "flat" spectrometers, and those in which the magnetic field is in the direction of motion of the electron, called the "helical" spectrometer. The University of Colorado spectrometer is of the "flat" type.

The two most common types of "flat" spectrometers are the 180° spectrometer and the double-focusing spectrometer. The 180° spectrometer uses a uniform magnetic field, and the focusing properties of the field are such that a point source gives a line image focused 180° downstream from the source. (See Fig. I). The

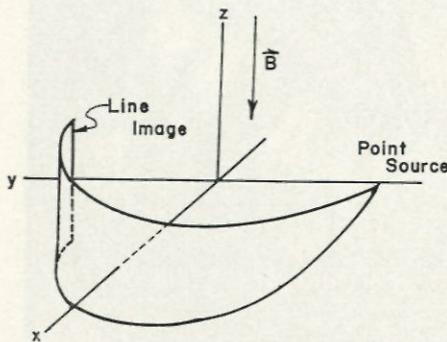


FIG. 1. THE LINE FOCUSING OF THE 180° SPECTROMETER

double-focusing spectrometer uses a field that varies with radius and a point source gives a point image. For instance, in optics, a cylindrical lens focuses similar to a 180° spectrometer, while the double-focusing system is similar to a simple spherical lens, in that all the light (electrons) is focused at a point. (See Fig. II). Aberrations and astigmatism also exist in spectrometers. The spherical aberration is the result of the non-point focusing or the non-line focusing of the electrons in the outer edge of the solid angle, which can cause an electron line to appear as a line of some finite width. As in optics, one can define a corresponding resolution which measures the ability of a system to resolve closely adjacent momentum

*There are also electric spectrometers.

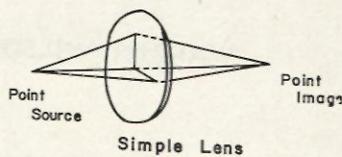
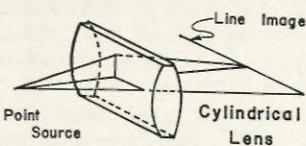


FIG. 2

groups of electrons. The resolution of the University of Colorado spectrometer can vary from 1 to 2 per cent at the largest transmissions to 0.05 per cent at small transmissions. This electron aberration can be reduced by shaping the magnetic field. Of the two, the double-focusing spectrometer is more versatile because it has a larger transmission (solid angle), and because it can work at smaller transmissions with high resolution.

The equation of a magnetic field whose strength is a function of its radial position can be given by

$$B(r) = B(a) [a/r]^n$$

where $r = a$ is the radius of the orbit at equilibrium, assuming cylindrical symmetry. (This equation and the others that follow come from theoretical studies of the stability of electron orbits in betatrons.) It is now necessary to find the value of n for which the magnetic field will become double-focusing. It can be shown that if the electron is displaced by a small amount in either the axial (z -direction) or the radial direction, it will oscillate around $r = a$ with frequencies given by

$$\begin{aligned} W_r^2 &= W_0^2 (1 - n) \\ W_z^2 &= W_0^2 (n) \end{aligned}$$

where $W_0 = \frac{V}{R} = \frac{Be}{m}$

These oscillations are approximately simple harmonic motion. For the electron to oscillate and not diverge exponentially from the equilibrium orbit, both W_r and W_z must be real or $0 < n < 1$. If the vertical frequency (W_z) and the radial frequency (W_r) of the oscillations are equal, then the electrons that are being emitted in all directions form a point source will arrive at the image plane at a single point. Therefore setting $W_z = W_r$:

$$W_0^2 (1-n) = W_0^2 (n); \dots n = 1/2$$

therefore the field is given by

$$B(r) = B(a) [a/r]^{1/2}$$

This is not the only value of n at which double-focusing will take place. There could be any number of radial oscillations for every axial oscillation, or:

$$sW_r = tW_z \quad (s, t = 1, 2, 3, \dots)$$

(See Fig. III). In the above case where

$s = t = 1$, the value of ϕ , at which the electrons are focused, is $\phi = \sqrt{2}\pi$ radians.

Trying to get maximum resolution along with maximum transmission has led to many different designs of spectrometers. There are three standard "magnet" designs of "flat" double-focusing spectrometers: 1) core in the center, 2) inside-out design, and 3) iron-free design. The theory of focusing is the same for all these designs, just the method of obtaining the required field differs. An iron form was chosen for the University of Colorado spectrometer because the shape of the magnetic field could be varied by shaping the iron pole faces, and because it would be difficult to achieve the environment suitable to operate the iron-free spectrometer. Also, less current is used. In the iron-free design a much greater current is needed to produce the required field than with the iron spectrometer. The inside-out design was chosen because no part of the magnetic circuit needs to operate with the iron near saturation.

The name "inside-out" refers to the coils, surrounding the working region rather than being "inside" the working region. With all these designs, the magnetic field could be changed by varying the current densities in the coils. The magnetic field determines the momentum of the electrons detected, according to the relation: $Be = \frac{MV}{R}$ where the elec-

tron is moving in a plane perpendicular to the magnetic field B with velocity V in a circular path of radius R . Since the charge e is constant, and the detector and the source are placed at a common radius R , the momentum of the electrons detected is directly proportional to the strength of the magnetic field. Therefore, it is possible to choose the range of monoenergetic electrons (the electron spectrum) you wish to examine by changing the magnetic excitation current.

Since there is a close mathematical analogy between the electric field in an electrolyte and the magnetic field

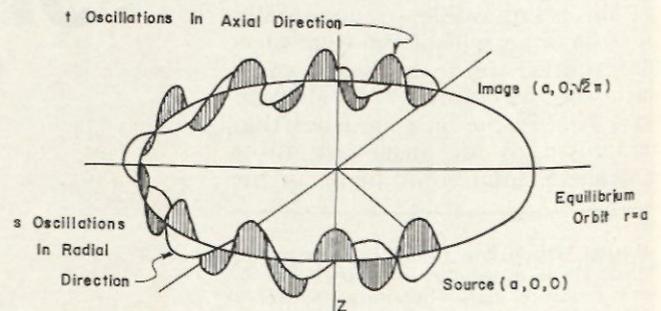


FIG. 3

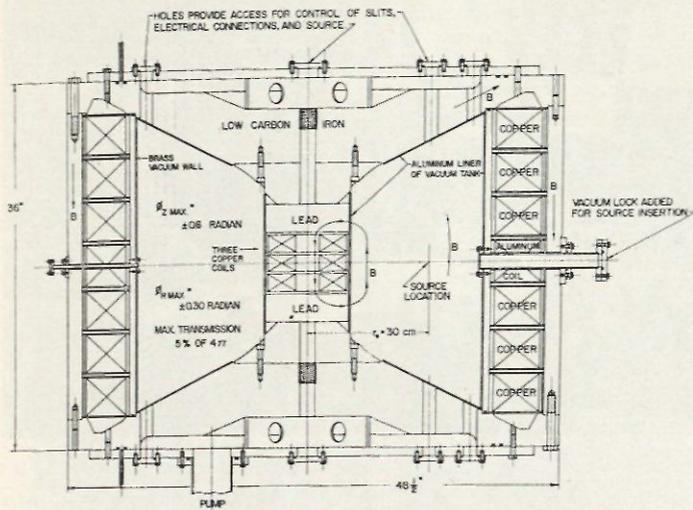


FIG. 4

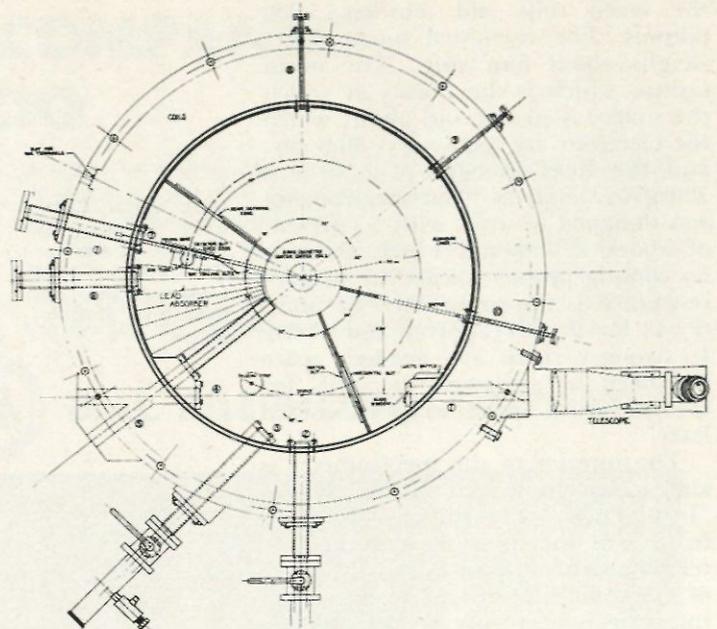


FIG. 5

between magnetic iron-pole faces, extensive studies were made with an electrolytic tank to determine what shape the poles had to be to achieve a field that varies as $r^{-1/2}$. The required shape was found to be that of a large cone. At small radii, the shape had to deviate from this cone with the pole faces coming closer together than was the case with the conical surfaces. (See Fig. IV). Three central coils were also added to maintain the field shape at small radii and to provide electrical control over the field at small radii.

With the inside-out design, the working region is surrounded by the coils and the pole pieces. This complete enclosure of the working region makes it difficult to have direct access to the source area and the detector area, which is needed for the insertion of the sources and for the control of the different apparatuses inside the spectrometer. Access can be obtained by going through the pole pieces or by going through the outer coil region. In Colorado's spectrometer both methods are used.

Any hole drilled through the pole pieces will affect the field shape near the hole, although this change in the field is pronounced only within, approximately, two hole diameters. At small radii, the pole faces are closer together and any hole drilled at small radii would affect the working portion of the field more. Also, since the magnetic field is bowed outward, any disturbance in the field at small radii would also distort the field at a larger radii. Therefore, if the holes are placed at large radii (near the outer vacuum wall) the field will be kept as uniform as possible. Accordingly many small holes were drilled in both the upper and

lower pole pieces. These holes were used mainly for the vacuum system and for the rods that controlled the different slit mechanisms.

Larger holes, which had to go through the outer coil region, for access to the working region were still needed. To do this, a space may be left between two adjacent coils (which essentially meant removing entirely the center coil in the outer coil region) or else one can drill directly through this central coil. It was found that the later method would affect the field shape the least. Therefore, the central coil could not be wound of ordinary wire since the holes would interrupt the current flow; hence a new technique of winding coils was used whereby the

coil was wound of pure aluminum foil four inches wide. Since the maximum hole diameter is about two inches, these holes can be drilled directly through the coil without affecting the current flow. This method was developed by Prof. Willis G. Worcester of the Department of Electrical Engineering on campus. Ten holes were therefore drilled through the coil, seven of which were of large diameter. All of these larger holes were placed in the unused sector of the field region between the source and the detector. (See Fig. V).

The completed spectrometer looks like a large tin can, fifty inches in diameter and thirty-six inches high (See Fig. VI). The spectrometer casing weighs about 6,700 pounds while

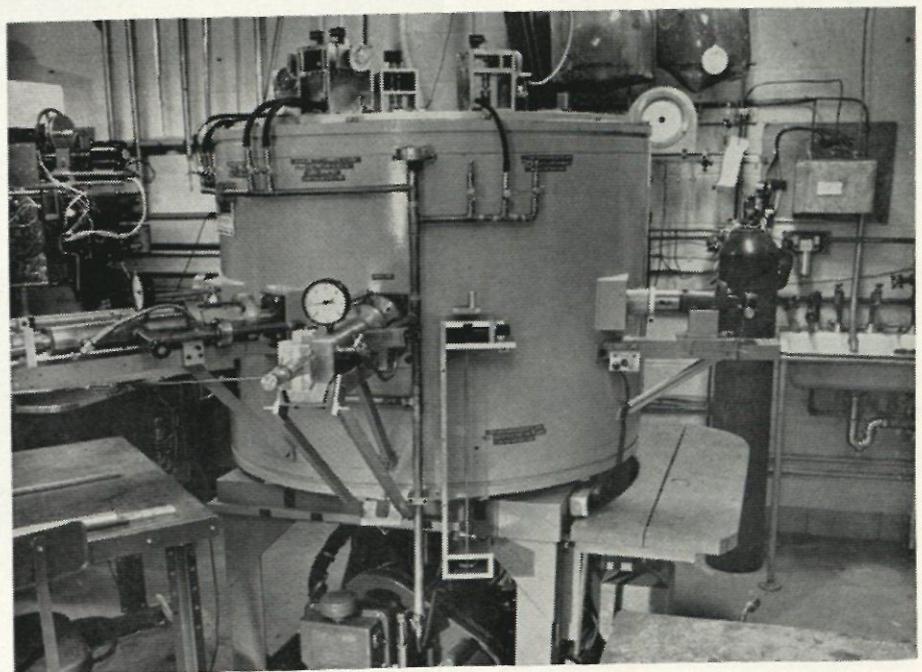


FIG. 6

the seven coils add another 3,000 pounds. The assembled spectrometer weighs about four tons. The mean radius, which is the radius at which the source is placed and about which the electrons are focused, is 30.0 cm., and the field strength of $r = a$ is 120 gauss amperes. The spectrometer was designed to work with a current of about 3 amperes, which presents no cooling problem since the magnet resistance is approximately 25 ohms ($P=I^2 R=(9)(25)$ approx. 250 watts). If stronger fields are needed, space has been left between the coils for cooling pads which may be added later.

The interior of the spectrometer is almost as complicated as the exterior "Lead Photo" The slits are the main feature of the interior, and they determine size and position of the beam of electrons transmitted to the detector. The position of the slit edges in the spectrometer are controlled by shafts which pass through the holes in the upper pole, rotating to change the slit position. The number of turns on turncounters outside the spectrometer indicates the slit position. The detector itself is a thin-window, GM (Geiger-Mueller) tube, located at an angle of $\sqrt{2}\pi$ radians downstream from the source, and especially constructed for this use. The detector has the feature that it can

JOHN KEITH, GRADUATE STUDENT IN PHYSICS, TAKING DATA FROM THE CONSOLE OF THE BETA-RAY SPECTROMETER.



be filled with a counting gas while the rest of the spectrometer is evacuated. Plans have now been made to use, in place of the GM tube, a scintillation counter to increase the versatility of the spectrometer.

Several research projects have completed using this spectrometer and several more are underway. At present the sources used come from the University of Colorado's cyclotron, or from commercial supplies of radioisotopes. The sources are made in the cyclotron and are then rused up to

the Physics Building to be put into the spectrometer for study. The shorter the half-life of isotope produced, the more difficult it becomes to make a sample at the cyclotron and transport it up to the Physics Building for study. When the spectrometer is relocated in the cyclotron building, it is planned to use automatic equipment to transport sources of short half-life from the cyclotron to the spectrometer. This will greatly increase the research possibilities of the spectrometer.

What's your group doing?



We're developing two specific systems for JPL spacecraft. The first accepts the data output of transducers and instruments on board and prepares it to pass through our communication channel. A data-handling system.



The other system allows us to efficiently transmit signals over great distances from the spacecraft to Earth and vice versa. It's an interesting operation. Thankfully, it's a shirt-sleeve operation.



Oh, I might wear a coat when I go to the cafeteria. The informality and freedom here is one way of saying that JPL conducts its affairs on a highly professional plane.



I've been trying to find an excuse to be unhappy for five years—since I graduated from the U. of Michigan. I haven't been able to do it yet.

You've just been talking to Benn Martin, Engineering Group Supervisor at Jet Propulsion Laboratory—responsible for R & D on lunar, planetary and interplanetary explorations. He's been at JPL for five years. He plans to spend fifty more here. If your future doesn't look as bright, you might write now to JPL.



JET PROPULSION LABORATORY

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Attention: Personnel Department 106

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THE BELL TELEPHONE COMPANIES

SALUTE: BOB DICIOCCIO

Bob DiCioccio (B.S.M.E., 1956) handles microwave transmission projects for Pacific Telephone in San Diego. Bob's job is to select and test sites, prepare plans and specs, obtain cost estimates, let bids, and supervise construction and installation of equipment. An important responsibility for a man with the company less than a year.

Bob proved his engineering ability early when he solved

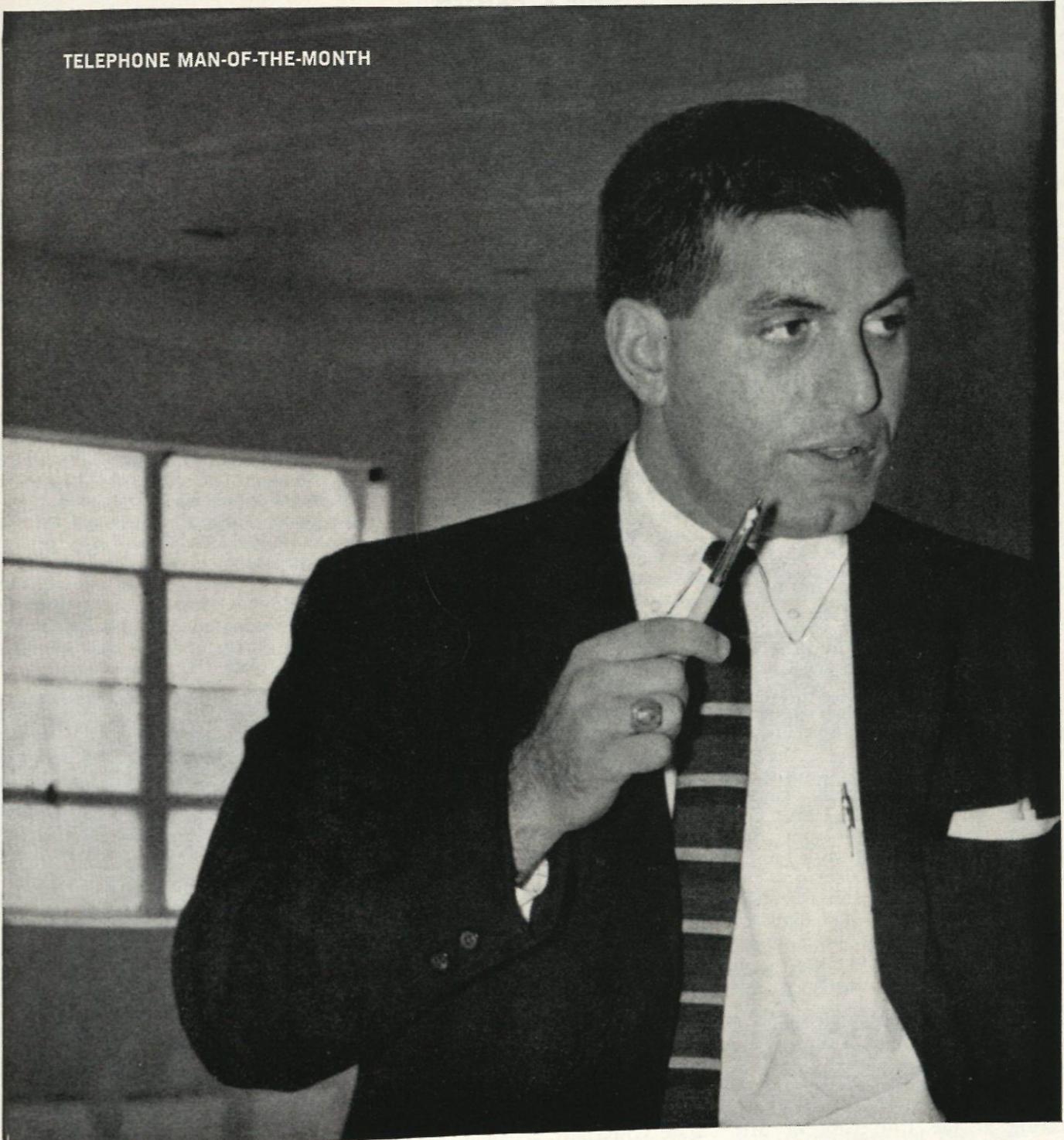
a tough problem concerning spring relay stress tension. A report of his findings won praise for its thoroughness and sound recommendations.

Bob DiCioccio and other young engineers like him in Bell Telephone Companies throughout the country help bring the finest communications service in the world to the homes and businesses of a growing America.



BELL TELEPHONE COMPANIES

TELEPHONE MAN-OF-THE-MONTH



ALUMNI NEWS

CHUCK HANSEN

HARRY A. CURTIS, B.S. (Chem.E.) 1908, M.A. 1910; received the Missouri Honor Award for Distinguished Service in Engineering from the University of Missouri, March 22. Curtis is a retired director of the Tennessee Valley Authority and former dean of the College of Engineering at the University of Missouri.

The Missouri Honor Awards for Distinguished Service in Engineering were presented to three outstanding American engineers and one corporation that designed and built the first orbiting, manned, American spacecraft. The award is presented to those who have made outstanding contributions to world progress through engineering.

Dr. Curtis was born in Sedalia, Colorado, in 1884. In addition to his B.S. and M.A. degrees from CU, he received a Ph.D. degree from the University of Wisconsin in 1914. He holds honorary doctor of science degrees from both CU and Wisconsin, and an honorary doctor of engineering degree from the University of Louisville.

He has served on the faculties of the University of Colorado, Northwestern University, Yale University, and the University of Missouri. He has worked as a chemist with several industrial firms, was chairman of the Division of Chemistry and Chemical Technology of the National Research Council in 1930-31, and he is now a member of the board of directors of the Oak Ridge Institute of Nuclear Studies.

Dr. Curtis retired as director of the Tennessee Valley Authority in 1957. He had previously served as chief chemical engineer before becoming dean of the College of Engineering at the University of Mis-

souri. He was dean for 11 years, returning to TVA when appointed director by President Harry S. Truman in 1949.

He is internationally recognized as a chemical engineer, educator and administrator. He is active in numerous professional societies, and is a past vice-president of the American Institute of Chemical Engineers. Dr. Curtis holds 25 U. S. patents and is a well known author of many technical journals. He is also author of the book, "Fixed Nitrogen."

GEORGE M. WILLIAMS, B.S. (C.E.) 1927; Director of Engineering and Operations for the U. S. Bureau of Public Roads, was presented the U. S. Department of Commerce Exceptional Service Gold Medal Award on February 14. The award cited Williams "for major contributions of exceptional value to the science and art of highway and bridge engineering and highway administration which have fostered economic and social advances for the people throughout the entire country."

Williams has been with the Bureau since 1927, and he has served in a variety of positions, including Bridge Engineer in Alaska and the Philippines, Regional Engineer, Deputy Commissioner for Engineering, and Director Offices of Engineering and Operations. Williams was awarded the Department of Commerce Silver Medal for Meritorious Service in 1957.

Glenn Murphy, 1929, M.S. 1930, C.E. 1937; has served as president of the American Society of Engineering Education during the past year. Murphy is currently head of the Department of Nuclear Engineering at Iowa State University at Ames.

RUSSEL M. HOLDREDGE, B.S. (Mech. E.) 1956, M.S. 1959; has been awarded a faculty fellowship by the National Science Foundation. Holdrege plans to study at Purdue University starting in June where he will work toward his doctorate. He is an assistant professor in mechanical and electrical engineering at Utah State University at Logan.

HARMON C. RICHARDSON, B.S. (C.E.) 1923; has been appointed chief engineer for Dravo Corporation's shaft and tunnel department. This department, which has been in existence more than 65 years, specializes in shafts, slopes, tunnels and mine face openings. Richardson has been with the Dravo corporation since 1929. He held various engineering and superintendent positions until 1956, when he was assigned to the shaft and tunnel department. Richardson graduated from CU with honors.



HARMON C. RICHARDSON

LAW AND THE ENGINEER

MARSHALL SILVER

The engineering degree is a versatile piece of paper. In most instances it is the means by which a young man gets an opportunity to gain practical experience in his chosen field. But for some students, this degree provides an opportunity to further his education and professional accomplishments—for example, it allows him to enter law school. It is a mistake to believe that the engineer cannot succeed in law, but he should recognize what is expected of him and he should realize the weak and strong points of his education.

One of the many important assets that an engineer has is the ability to think logically and clearly. A lawyer must be able to evaluate data and condense it into a clear, meaningful argument. The four years engineering curriculum tends to develop the basic techniques of logical thought. A student cannot hope to encounter every type of problem in his course work, but he can acquire the ability to start at the beginning of a problem and solve it by clear thinking.

Other qualities associated with engineering are self-reliance and patience. He develops self-reliance through the process of applying his knowledge to the physical world both in simulated problems in the classroom and actual problems in the laboratory. In addition, he develops patience through the process of "grinding out" solutions to horrendous mathematical puzzles and other common types of necessary "busy-work." These are both necessary traits of the successful lawyer.

Thus the engineer brings many necessary qualities to law school, each fostered by his technical education. Unfortunately, there is an equally long list of deficiencies that are a direct consequence of his course of study. The engineer usually lacks the ability to write well. Legal writing, like technical writing, must be clear. The jumbled technical report and the ambiguous legal paper both lead to the same consequences — confusion,

waste and expense. Further, the poor legal draft may place the lawyer's client in jeopardy.

At times, the engineer lacks social sensitivity. He has a tendency to think in terms of physical rather than sociological problems. Consequently, he does not relate his work to society. Society and his work are two independent spheres. On the other hand, the lawyer works directly with people and their problems, hence he must have a great deal of social awareness.

Admission into law school in many instances depends on whether or not the student has strengthened the good parts of his engineering education and eliminated its deficiencies. Most schools grant admission according to undergraduate grades and rank in class. Law schools have found that engineering students in the top of their class usually have few deficiencies. Good students have acquired the ability to learn quickly and well, a prime requirement for the lawyer. Furthermore, through his extra-curricular activities, the top student has developed a social awareness that will help him understand and communicate with people.

A further requirement that is becoming more and more necessary in qualifying for admission to law school is an acceptable score on the law school admission test. This test is administered by the Educational Testing Service. Such subjects as literature, art, music, and history are covered on this test. These are subjects that are given only scant attention in a standard engineering curriculum; hence the average engineering student knows little about them. Again, it is the top student who will do well on this test because he is usually well read.

Specific requirements for admission to law school vary among institutions, but most schools require at least three years of college training, and many schools require a bachelor's degree. Few schools require specific pre-law courses, but it would be wise for

the student of engineering to familiarize himself with the requirements of the school that he wishes to attend.

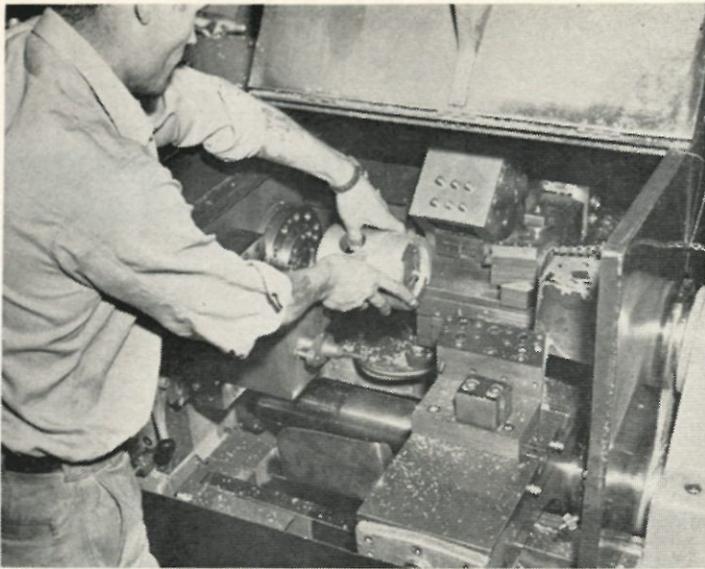
The lawyer with an engineering background may choose either to use or not to use his engineering training in the legal profession. Many of the top law graduates, no matter what their pre-legal training, go into general practice. These lawyers handle any type of case that is presented to them irregardless of the type of work involved. An engineer engaged in this field might expect to use his technical knowledge as little as ten per cent of the time, but his specialized training would be invaluable to him when dealing with clients in the engineering or scientific professions.

For the patent lawyer, engineering and law is an essential combination. The patent lawyer may help prepare the specifications needed in order to secure a patent in the United States or in foreign countries. He is also concerned with protecting his client from patent infringements and in some cases he may also assist in exploiting the invention if it has commercial value.

Another possibility is corporation law. The corporation lawyer acts as an agent for the corporation and as such he advises and represents the officials in all legal actions. The lawyer, if he chooses this speciality, must be prepared to move to the eastern part of the country since most corporations are centered on the eastern seaboard. This may seem trivial to some people, but many people from the West find eastern living distasteful.

A small but growing field for the western engineer is the specialty of water law. Water is essential to the growth of the West and as with any scarce resource, the law concerning it has become highly specialized and technical. But since it is so important in the West, anyone who plans a western law career must have a fundamental knowledge of water law.

(Continued on page 49)



MOUNTING A PISTON ON A LATHE ASSEMBLY IN THE FINISHING LINE.

COLORADO INDUSTRIES

JIM TOEVS

If you own an American-made car, the chances are excellent that your pistons were made by Triplex of America, located in Pueblo, Colorado. Triplex supplies pistons to major American automobile manufacturers, engine manufacturers, and to jobbers throughout the United States and the world.

There are three main steps in the construction of a piston. First is the smelting of the aluminum alloy to be used in a particular type of piston. The next step is casting the molten alloy into the desired shape. Finally, the piston is turned, grooved, and ground to the specifications of the order, packaged, and shipped. One of the main reasons for the company's success is that it is self-contained, having the smelter, foundry, and machine shop all at the same location.

Piston construction begins at the smelter, which has three open-hearth furnaces. The largest furnace has a capacity of fifteen tons, and takes twelve hours to run a heat of this size. The temperature of the furnace walls climbs to about 1800° F, and the temperature of the metal to about 1300°. At the end of the smelting process the molten metal is poured into thirty-pound ingots, which are cooled and stored for use in the foundry.

At this point, samples of the alloy are tested for content on the plant's arc spectrograph. Seventy-five per cent of the Triplex pistons are made of the "F-132" alloy. This alloy is about 85% aluminum, with 2-4% copper 10% silicon, and small (but precise) amounts of magnesium,

iron, nickel, zinc, manganese, titanium, lead, tin, chromium, and sodium.

From the smelter, ingots are taken to the foundry, where they are fed into holding furnaces. Hand-ladles pour the re-melted metal into automatic molds. One man usually operates two or more molds, placing "struts," if necessary, into the mold, closing the mold, filling it, and then, after mold has opened automatically, picking the hot piston out of the mold and putting it in a bin. The term "strut" refers to the steel inserts molded into the piston to control thermal expansion in the finished product. The three types of struts are the autothermic, the conformatic, and the round band. The molten alloy takes about thirty seconds to set. The pour-holes in the mold are connected to the piston section by cylindrical pathways. The resulting arms on the cast piston are called "risers." Since the risers are geometrically above the piston when the metal is setting, the impurities migrate up into the risers.

After the piston has cooled, the risers are chopped off, the piston is tempered in a heat-treatment oven, and then taken to "foundry inspection" for a dimension check. If the piston is to be shipped to the customer for final machining, the sides are pre-turned and the head faced to 0.125 inches over the final size. This eliminates the cost of shipping for the removed waste material. If the piston will remain at Triplex for final machining, it may be pre-turned to 0.160 inches over, or may not be pre-turned at all. Some pistons are

molded with a complex contoured head and are not faced. This head is a special configuration to improve the distribution of fuel in the combustion chamber.

For final machining, inspection, and plating, the pistons go to the machine shop, which served as a hangar during the war. (Triplex is located beside the Pueblo Memorial Airport). The finish machine department has eight finishing lines which are set up for different sizes and specifications. The first step is to bore and face the piston skirt. This important step determines the surfaces on which the piston will be centered for each of the remaining cuts. Now a special lathe assembly

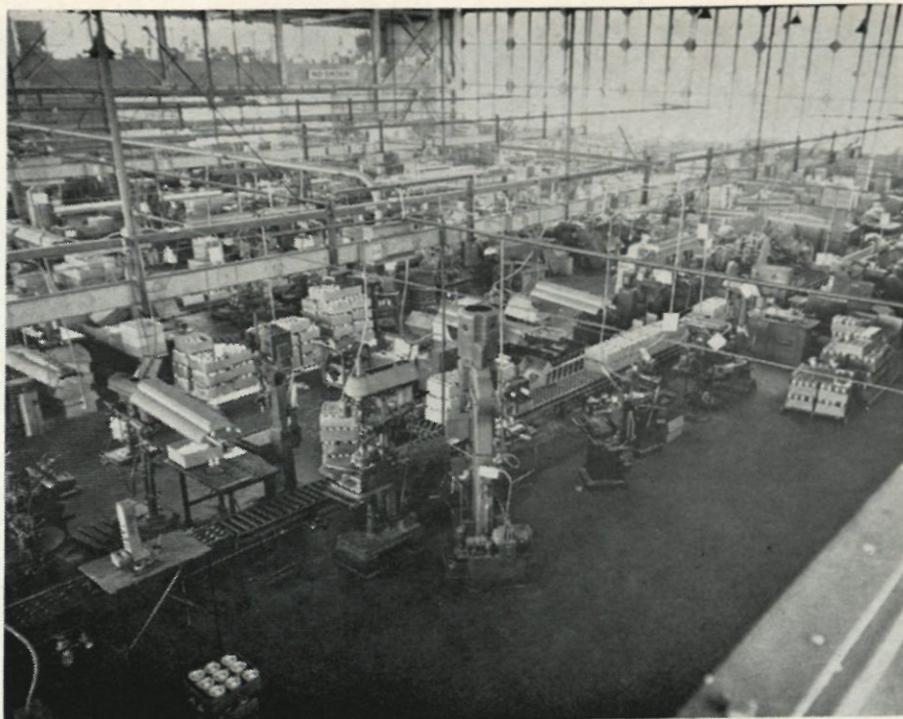


REMOVING PISTON FROM MOLD IN THE FOUNDRY. NOTE HAND LADLE BEHIND WORKER.

rough-turns the outside diameter to 0.014 inches over, cuts ring grooves and chambers, and drills center holes. A grinder rough-grinds the skirt to within 0.005 inches, and finish-grinds the "lands" (the surface area between the grooves). The wristpin hole is then bored to $\pm .0001$ tolerance of its final specification, the lock ring groove is machined if the design requires it, and any necessary slots are cut. The piston is weighed, and a special machine evenly removes metal so that all pistons of a particular design will weigh within two grams of each other. A grinder finishes the piston skirt to an elliptical contour and it goes to final inspection, where its diameter, weight, pin hole, etc., are checked at a constant temperature of 70° F.

After inspection, most pistons are tin plated, and all are then pin fitted. The pins and pistons are color-coded for size and matched to provide proper clearance. After pin fitting, the pistons are packaged and shipped.

Triplex, founded in Chicago by Frank I. Lamb, originally built parts for drycleaning machines. During World War II, the plant constructed such items as tank pistons and machine gun parts. Immediately after the war, the company switched to



TRIPLEX FINISHING MACHINING DEPARTMENT, SHOWING VARIOUS LATHE ASSEMBLIES, DRILLS, AND OTHER FINISHING OPERATIONS.

automotive parts, and, in 1949, moved to Pueblo to make pistons. There is also a Cincinnati plant, which primarily makes valves. The Pueblo plant employs about 600. Tri-

plex has warehouses throughout the United States and Southern Canada. For employment information, write Mark Rochon, Triplex of America, P. O. Box 666, Pueblo, Colorado.

PROGRESS in Engineering

DENVER our central engineering office

HEADQUARTERS FOR DESIGN, CONSTRUCTION AND MANUFACTURING SERVICES TO INDUSTRY

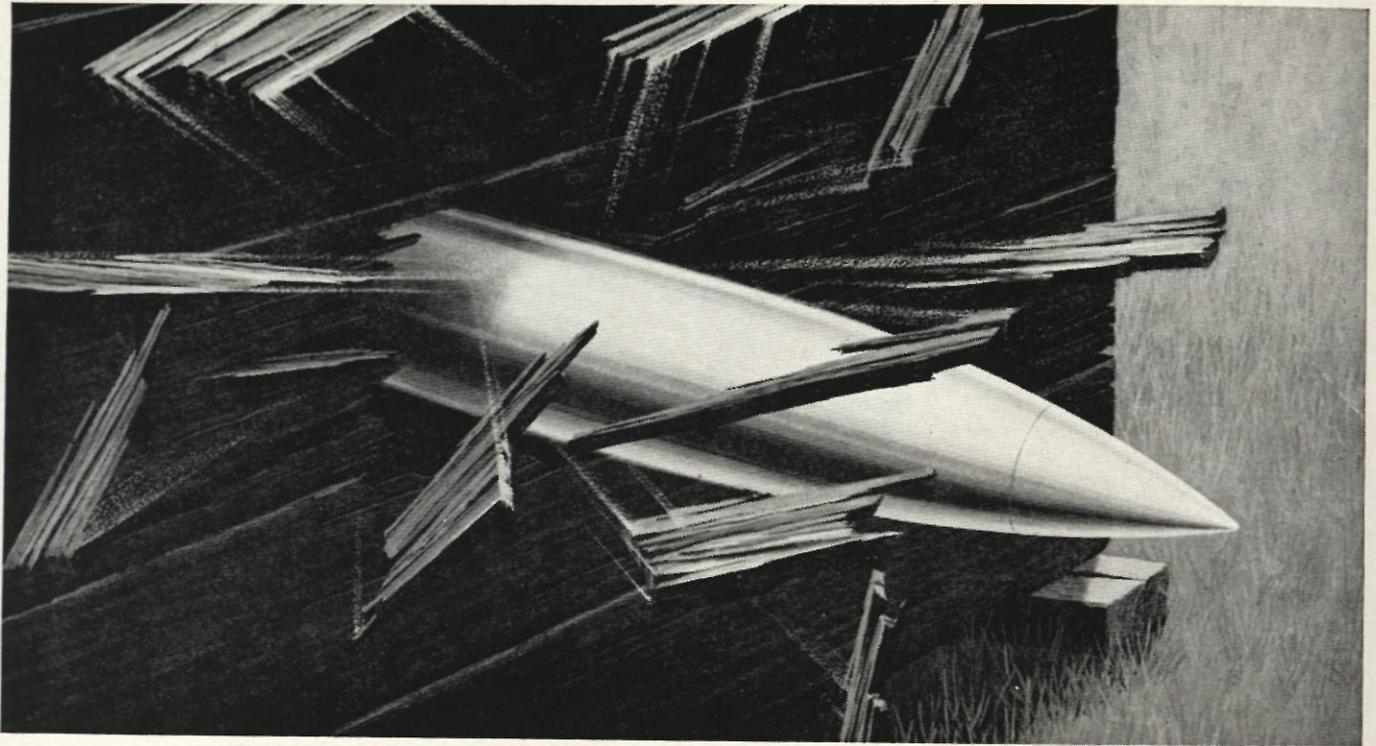
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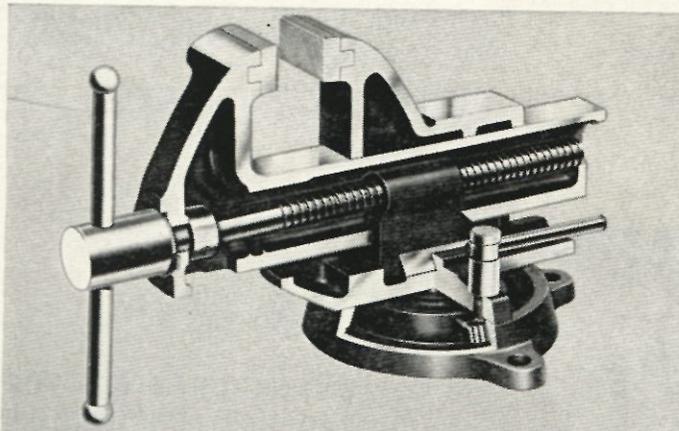
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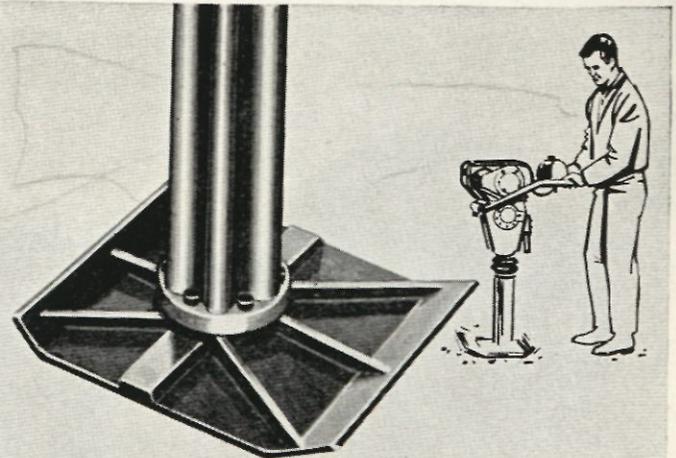
P. O. Box 5888, Terminal Annex, Denver, Colorado



Malleable artillery shell pierces 2 feet of solid oak at a velocity of 2,000 feet per second. In U. S. Army tests, pearlitic Malleable 105 millimeter shells were fired at 112% of rated maximum pressure. The new Malleable shells pierced the solid barricade, performing to the exacting requirements of the specification . . . proof of STAMINA.



"Guaranteed for Life" is the hallmark of confidence the manufacturer of this vise has had in its all-Malleable housing since first designed in 1917. These machinist's vises really earn their reputation as the most abused tool in the workshop, and about one million are now in use. All carry this unconditional guarantee . . . proof of STAMINA.



Pearlitic Malleable shoe for air-powered compactor delivers 900-pound blows at the rate of 350 per minute. Day after day, month after month, this rugged casting batters away on dirt, gravel, clay and rocks without significant wear or damage . . . proof of STAMINA.

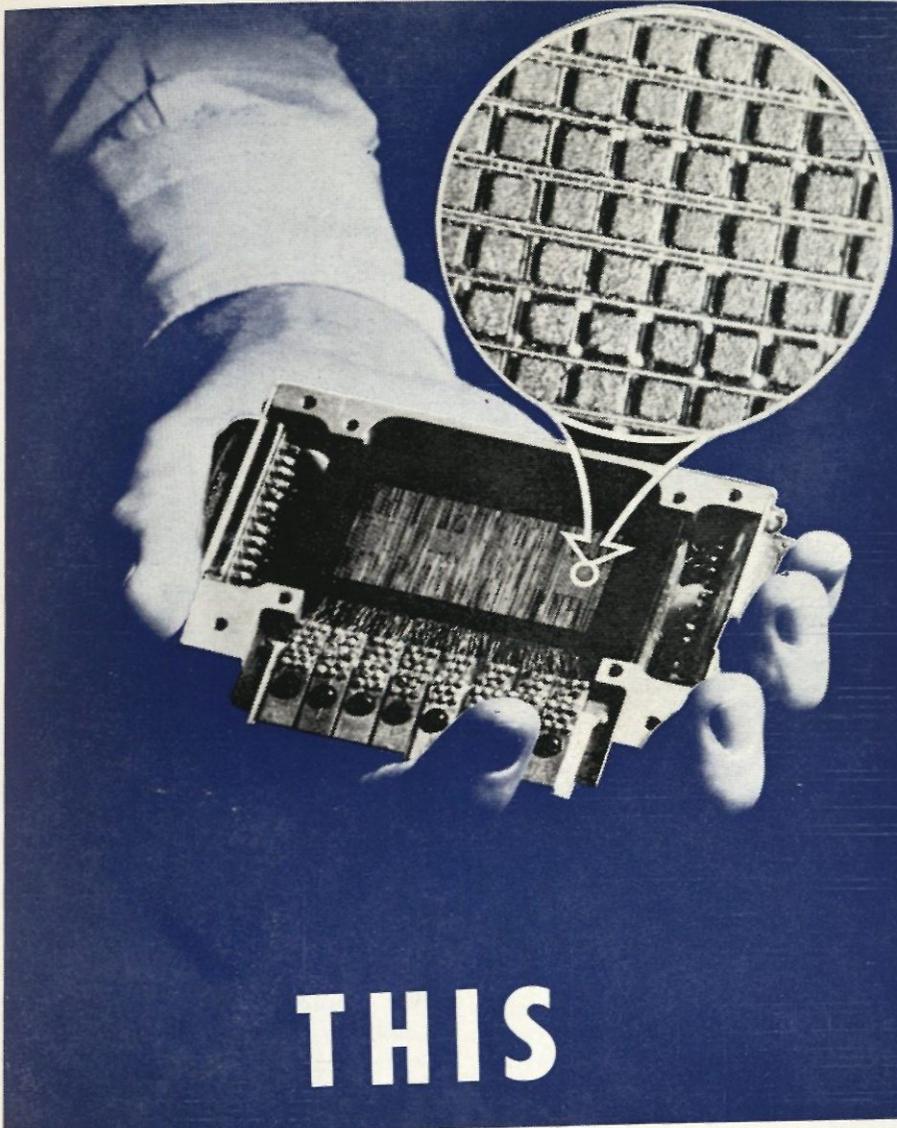
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THIS

TODAY

JOE CAYER

WAFFLE IRON MEMORY DEVICE

A new magnetic memory device that looks somewhat like a miniature waffle iron has been developed at Bell Telephone Laboratories. Because it has one of the shortest storage paths for a single bit of any magnetic memory device, the structure is extremely compact, and can operate at high speed on low input power.

The new memory will be particularly useful for large-capacity, economical stores operating at read-write cycles of less than a microsecond. It looks promising for computers and switching systems which are now using ferrite cores and thin films.

The waffle-iron device consists of a base plate made of a high permeability ferrite in which a grid of slots is cut, leaving a regular array of

rectangular posts. This gives the surface the appearance of a miniature waffle iron. Pre-printed wiring patterns—a set for the read-write and a set for the digit-sense wires—are placed in the slots. An overlay of square-loop magnetic material—such as a type of permalloy—is laid across the tops of the posts.

Information is stored in the overlay material between the posts in the direction of magnetization of the magnetic flux. The width of a slot is the effective length of the magnetic path in the storage material. The high permeability base and the square-loop material connecting a pair of posts form a closed magnetic flux path. One type of waffle-iron memory has posts 100 mils long and 30 mils wide and a slot width of 30 mils.

Both destructive and nondestructive waffle-iron memories have been built; the basic difference is in the magnetic overlay. Destructive memories use an overlay of a single magnetic material. Nondestructive memories use an overlay of two magnetic materials—one for storage and the other for sensing. When a nondestructive memory is read, only the sensing material is switched; thus the memory can be interrogated indefinitely without affecting the stored information.

WALK ON AIR

A permanent magnet with a "memory" which can in effect, be turned on and off has been produced by Westinghouse Electric Corporation. The on-off behavior comes from a unique new magnetic circuit in which the permanent magnet is the key element.

The circuit's capability has been demonstrated by an "earth walk" much more difficult than any walk in space—upside down on the underside of a steel beam against the full pull of gravity. Attached to the soles of a man's shoes, the magnets clamped his feet securely to the beam to support him and freed them when he wanted to take a step.

The new circuit differs from ordinary permanent magnets in three important ways: (1) it exerts strong magnetic force at one end while exerting hardly any at the other; (2) the strong and weak magnetic poles can be switched end-for-end easily and at will, thus, in effect, turning the magnetism on and off; and (3) it remembers its direction of greatest magnetic pull indefinitely. Lacking these features, conventional permanent magnets attract objects without preference, cannot be easily controlled, and have no magnetic memory. The new circuit combines the desirable features of the perma-

nent magnets and electromagnets. Like the permanent, it needs no applied energy to create a strong magnetic field. But like the electromagnet, the strength of the field can be varied easily and continuously, while the magnetic condition is remembered indefinitely.

The circuit is described as a "three-layer sandwich" by its developer, typically about one inch square and a half inch thick. The middle layer is a ceramic magnet. The two outer layers are thinner pieces of soft steel which act as magnetic "funnels" that concentrate the magnetic lines of force of the magnet into the end areas. The funneling effect creates a pull of about 30-50 pounds at either end, where a pair of opposite magnetic poles exist. Two metal pieces, or keepers, one at each end, complete the circuit.

The memory of the circuit and its on-off feature come from transfer of the magnetic lines of force, or magnetic flux, which is within the system. The transfer can be made mechanically or by a short pulse of low-voltage current. Mechanical transfer is accomplished by moving the keepers at the ends of the magnet. The keeper first placed in position is always held with the strongest force. Removing the keeper automatically shifts the magnet's flux, and its greatest pull, to the opposite end. The magnet always remembers which keeper was put in position first by exerting maximum force on it.

For electrical switching, a coil of wire is wound around one pole of the magnet. A short pulse of current is sent through the coil in such a direction as to oppose the magnetism at the strong end of the circuit. This transfers the flux to the weak end, and the same shifting occurs as that in the mechanical shifting.

The circuit may be used as a remotely controlled lock for the doors, trunk, and hood of automobiles, all under control from pushbuttons in the driver's seat. It could also serve as a magnetic memory unit for digital computers. The idea may be used for magnetic shoes to enable spacemen to have a kind of artificial gravity and enable them to walk around in the weightlessness of outer space.

VERRAZANO-NARROWS BRIDGE

The United States Steel Corporation is producing wire for the cables going into the new Verrazano-Narrows bridge. The bridge will link Brooklyn and Staten Island and will be the world's longest suspended span. The total length of the bridge will be 13,700 feet while the length



VERRAZANO-NARROWS BRIDGE

of the suspended structure is 6,690 feet. The length of the main span is to be 4,260 feet, 60 feet longer than the Golden Gate bridge, and the side spans will be 1,125 feet. Its width will be 103 feet, with twelve traffic lanes.

The crews spinning the more than 38,000 tons of wire for the cables have been working one shift per day, but will start a second shift to speed completion of the four 7,205 foot-long cables. Each cable will measure $35\frac{7}{8}$ inches in diameter. About 145,000 miles of 0.196-inch diameter galvanized steel wire will go into the cables. The wires will actually be placed parallel to each other instead of being twisted or braided as the word "spinning" suggests.

ROTARY SURFACE GRINDER

A rotary surface grinder taller than a two-story building is helping General Electric Co. reduce delivery time on steam turbine-generators and marine propulsion plants. The 30-ton, 25-foot-diameter grinding surface table makes this the largest known machine of its type in the world today. The table has an area of more than 490 square feet. Capable of removing ten cubic inches of stock per minute, General Electric engineers predict the grinder will cut machine time in half. The grinder is now in operation at GE's Lynn, Massachusetts plant.

Work pieces up to 85 tons can be ground to a guaranteed flat and parallel accuracy of .002 inch. The

grinder will be used to finish grind steam joint surfaces on turbine heads and casings and flat oil joints on gear casings. The department where the unit is used manufactures steam turbine-generators for power generation and marine propulsion plants. The column unit, with its counterweighted head, weighs 150 tons and provides the rigidity required for the 250 hp. drive. The entire column is supported on three shoes for adjustment of wheel alignment.

Flat work accuracy is accomplished by hydraulically actuated wedges that raise and lower the column to adjust the plane of the grinding wheel parallel to the table. From pulpit, located just to the rear of the grinding wheel, the operator can read instrument increments of .001 inch and follow the vertical movement as the wedges are positioned. Both vertical and in-and-out travel allows the operator to move his power driven pulpit into the work area to inspect the surface and set the stops for the power operated wheel dresser.

The design of the grinding head is unique in that it uses 30 separate stones of standard size for easy replacement. When in operation, sliding guards mounted on a monorail completely enclose the grinder and contain the coolant spray. Coolant, slung at high volume under the stones, washes sludge and chips from the work surface. The coolant is recirculated and filtered at a rate of 400 gallons per minute through a paper filter unit.

NEW COLOR TV TUBE

A new color cathode ray tube for television sets, that can be produced at substantially lower cost than present color television tubes, has been patented by David M. Goodman of New York University. The tube uses a single electron gun instead of three guns is now standard practice in the industry. The new tube also dispenses with the mechanical "shadow-mask," a selection device that substantially cuts down the brightness of the projected picture.

The Goodman tube has a target screen consisting of repeating groups of vertical color strips and thin indexing strips, all deposited on the face of the tube. When bombarded by the scanning beam released from the single electron gun, the index strips give off short bursts of ultraviolet and X-ray index signals, which locate the position of the electron beam on the target screen. Attached to the electron gun are light pipes which pick up the index signals and send them through the neck of the tube to very rapid gating circuits. These circuits sample the different video color signals, and then control the modulation of the electron beam to insure registry of the different color signals on the target screen.

The new tube does not employ the wire grids and apertured masks used by the expensive color cathode ray tubes now in use. Instead, the Goodman tube provides a unitary, non-vibrating, sandwich assembly of index strips and color strips on the face plate of the tube. The index strips operate at the same voltage as the color strips, requiring no additional

high power voltage power at the target screen. Also, because the index signals are transmitted as electromagnetic radiation to the light pipe members, additional high voltage circuitry is not needed. This arrangement, which simplifies the target screen and index signal pick-up structures, makes the tube less expensive to produce. In addition, the new tube is better adapted to meet the broad range of environmental conditions likely to be imposed by industrial and military users.

Initial production plans are for a 600 color line tube, with a brightness capability of 75 foot-lamberts unmodulated, to be available for television receivers this autumn. The tube, in addition to its obvious use in television receivers, is expected to have wide application to information display and electronic data presentation systems for civilian use and for military installations.

NEW PORTABLE TV TAPE RECORDER

A new portable television tape recorder, weighing only 68 pounds and designed to record closed circuit educational television on economical one-inch wide tape, was announced by Precision Instrument Company. Deliveries of the fully transistorized device, which will record audio and a full 3.5 megacycle band width signal output from any image orthicon or vidicon camera, will begin this spring. The two-cubic foot sized recorder is called the PI-3V.

The easy-to-operate PI-3V will record 96 minutes of programming on a single 10½-inch reel of one-inch



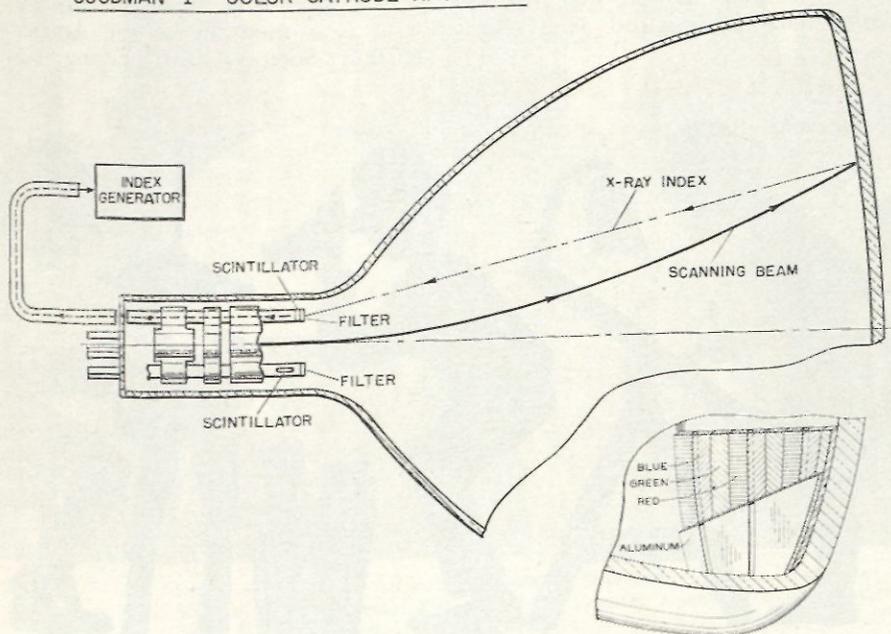
PORTABLE TV TAPE RECORDER

tape. With only two recording heads as opposed to present non-portable recorder's four, the new unit places the video signal on tape by a helical scan method using a 180 degree tape wrap. Tape moves at a slow, 7½-inches per second.

Priced at a fraction of TV recorders on the market, the new Precision recorder fulfills a long-sought requirement in hundreds of United States closed circuit educational television systems, according to a spokesman at Precision Instrument Co. Exceptional illustrations of audio-visual instruction can be filed and replayed 100 times or more. Similarly, since the recorder's construction and tape drive and scanning performance ensure complete interchangeability of tapes among all PI-3V units, noteworthy tapes can be rotated among institutions. Teacher evaluation and acquisition and storage of exceptional lesson material, such as scientific experiments for scholastic audiences, are other uses for the unit.

The device is portable, requires only 110 volts, and consumes only 350 watts, an important consideration when portable power supply is needed. This, coupled with the simplicity and light weight of present closed circuit television cameras and audio recording equipment, extends the educator's sources of audio-visual material. Operation of the PI-3V, from threading the tape to recording under various audio and visual levels, is no more complex than running familiar audio tape recorders.

GOODMAN I - COLOR CATHODE RAY TUBE



GOODMAN I - COLOR CATHODE RAY TUBE

The Colorado Engineer is the engineering journal of the University of Colorado, published four times a year. Most of the work of chasing down the material and of putting the magazine together is managed by the students. In this, the final issue for the year, we would like you to

MEET

The COLORADO Engineer

STAFF

LOWELL BROOKS

Lowell Brooks, this year's editor, is a fifth year student in Applied Mathematics. This graduate of La Junta High School, La Junta, Colorado, has been rather busy at C. U. He is a member of Tau Beta Pi, Sigma Tau, and Sigma Pi Sigma. He also works in the Department of Applied Mathematics Numerical Analysis Center as an Assistant Programmer. He teaches a lab section in computer programming and helps students learn to run the digital and analog computers. Next year he will start work towards a doctorate in Continuum Mechanics at the University of Maryland in College Park, Maryland.

PAT BROOKS

Pat Brooks has been on the staff of the COLORADO ENGINEER for three years. This last year she served in the capacity of business manager. This

native of Salida, Colorado, began as a student in Chemical Engineering, but after three years, finally decided that she would rather go into Arts and Sciences. Next year, Pat will be in College Park, Maryland.

CHERYL ANDERSON

Cheryl Anderson from Short Hills, New Jersey has been Office Manager of the COLORADO ENGINEER this past year. Cheryl is a freshman in Arts and Sciences; and is majoring in Political Science. Unlike most students on the staff, she is entirely dependent on her parents for her education. Cheryl enjoys many outdoor activities including woodsies. She also enjoys F.A.C., parties, and a certain Texan by the name of Dan.

In addition to Office Manager, Cheryl has also helped out in circulation, advertising and as a secretary.

LARRY L. HUSTON

Larry L. Huston is this year's assistant editor (he edited the joke page) and next year's editor (no joke). He came to the College of Engineering shortly after spending three years in the Army. This is his second year on the staff and his third year in school studying Civil Engineering. He is active in ASCE, the Newman Club, Chi Epsilon, Sigma Tau, and Tau Beta Pi. In addition, he works approximately ten hours a week in the Dean's office.

RON BLACKWELDER

Ron Blackwelder, who hails from Brighton, Colorado, is a senior in Aeronautical Engineering. He has worked two years on the ENGINEER, last year as layout editor and this year as production manager. In addition to spending some time in classes, Ron is a member of the American Rocket Society, Buff Flying Club.



Sigma Tau, and Tau Beta Pi. He also works 27 hours a week, cooking for the Farrand Sweethearts. In spite of all this, Ron has been able to maintain a 3.65 average.

ROSS FRAKER

Ross is a junior in Applied Math. who came to C.U. from nearby Greeley. He became a member of the Superior Student Program as a freshman and steadily fell into more activities, the chief ones being varsity wrestling and Alpha Phi Omega, a national service fraternity. This year, in addition to these, he acts as circulation manager for the COLORADO ENGINEER in between hashing, grading papers, being active in SIAM, Tau Beta Pi, and Sigma Tau, and going to class now and then. Among his other outside interests are coin collecting, listening to records, and a certain Miss Deanna Borden from C.S.C., to whom he is engaged to marry at the end of the coming summer. He lacks only something to keep him busy, and even this deficiency will be filled by his position as business manager of the ENGINEER next year.

MITCHELL ALLIES

Mitchell Allies is a sophomore in Engineering Physics. He has a 3.5 average and enjoys courses in both Science and Humanities. During summers he likes to fish, hike, and

LAYOUT SESSION,
FIRST STEP TOWARDS
ANOTHER ISSUE.



participate in outdoor activities. After a long school year, he is looking forward to a summer in which he can let his mind loaf and contemplate some interesting ideas.

CHARLES HANSEN

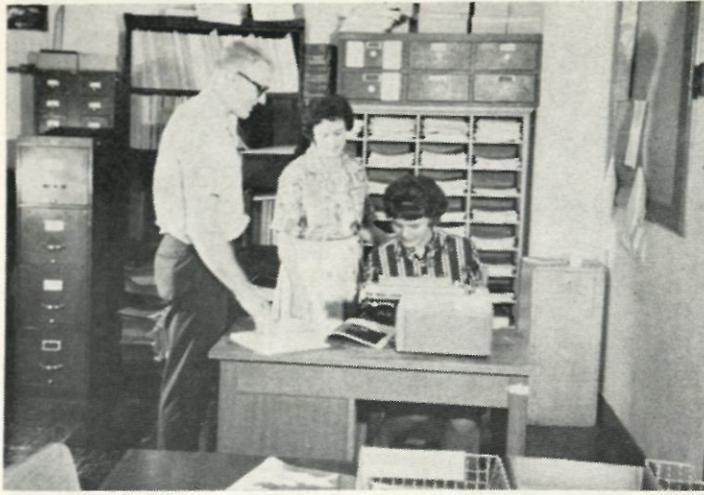
Charles Hansen, Alumni News reporter, is a sophomore from Gunnison, Colorado. He is majoring in Aeronautical Engineering and intends to do graduate study. This is his first year on the COLORADO ENGINEER staff. He enjoys hunting, fishing, and F.A.C. He is presently studying under a Perrine Scholarship.

JIM TOEVS

Jim Toevs is a junior Engineering Physics major from Pueblo, Colorado. A Boettcher Scholarship and part time work at the cyclotron help him through school. His outside interests include tennis and music. He is a member of three University bands, a member of Sigma Tau, Kappa Kappa Psi, the national band honorary, Sigma Pi Sigma, the Physics honorary, and participates in the superior Student Program and the NFS Summer Research Program.



FRONT ROW: (LEFT TO RIGHT) CHERYL ANDERSON, JO ANN CRAM, PAT BROOKS, ELLEN CARR.
SECOND ROW: LOWELL BROOKS, ROSS FRAKER, LARRY HUSTON, DAVE PARKHURST, CHUCK HANSEN.
BACK ROW: BURTON DWYRE, MARSHALL SILVER, RON BLACKWELDER, PING CHAN, FRED LOVE.



SAY, THAT'S A PRETTY GOOD JOKE.

MIKE PELOQUIN

Mike Peloquin, the Head Proofreader of the ENGINEER for the past three years, is an Arts and Sciences senior majoring in Sociology. He is an "Old-Timer" with six (miserable) years of active duty—4¾ years in the Air Force and 1¼ years as a cadet at West Point. Mike is presently chairman of the Membership Committee of the campus chapter of Alpha Phi Omega, the National Service Fraternity, and the Assistant Scoutmaster of troop 175. He plans to work as a Scout Executive in the Boy Scouts when he graduates (finally) next February.

ELLEN CARR

Ellen Carr, Book Reviews Editor for the COLORADO ENGINEER, is a sophomore in Mechanical Engineering. She is a member of the Superior Student Program, Tri-C, and the Boulder Chapter of the Society of Women Engineers, and has served as Secretary of Inter-Varsity Christian Fellowship during the past semester. Her home is near Elbert, Colorado, where her family ranches.

MIKE MARTIN

Mike Martin serves as advertising manager for the COLORADO ENGINEER. A former frustrated aeronautical engineer, Mike transferred after three

semesters to Arts and Sciences where he found himself as an Economics major. He is a sophomore with a 3.00 average and calls Grand Junction, Colorado, home. Mike's main extra curricular activity is learning to play a guitar — he wants to become a folksinger or at least accompany other folksingers.

JOE CAYER

Joe Cayer is a junior political science major. He has written for the COLORADO ENGINEER for two years. He plans to teach at the college level after doing graduate work in his major.

DAVE PARKHURST

Dave Parkhurst, articles editor for the Engineer, is a junior in Applied Math. He came to engineering from anthropology, and plans to do graduate work in energy ecology. Dave has participated in the Superior Student Program, in the engineering Undergraduate Research Program, and in the Winter Undergraduate Program of the Institute of Arctic and Alpine Research. Other interests put him in such activities as Alpha Phi Omega national service fraternity; Sigma Tau engineering honorary; the University Hiking Club; and the Rocky Mountain Rescue Group, of which he is presently secretary.



THE COLORADO ENGINEER BANQUET.

ARLAN SIMMONS

Arlan Simmons, going to school in his own home town, is a junior in Electrical Engineering and Business. His job on the COLORADO ENGINEER is pounding the pavement for the Advertising Dept. Married and the father of three boys, he spends his spare time with his family and motorcycle racing. After working as a draftsman for five years, Arlan decided that the college route was the fastest way to success.

MARSHALL SILVER

Marshall Silver began his engineering training at the Colorado School of Mines as a mining engineer. Extreme claustrophobia made it impossible for him to continue his subterranean existence so a move to the surface and the civil engineering program of the University of Colorado was necessary. Last year he worked for a Denver civil engineering firm, helping to develop transmountain water diversions in Colorado and he has returned to school in order to get his degree. Marshall's extra-curricular activities include keeping above a B average and participating in rifle and pistol tournaments. Originally from Sherman Oaks, California, Marshall now makes his home in Boulder.



PROFESSOR MALER RECEIVING AN AWARD FOR FIVE YEARS SERVICE TO THE COLORADO ENGINEER.



INCOME THE NEW—LARRY HUSTON, EDITOR, AND ROSS FRAKER, BUSINESS MANGER; AND OUTGO THE OLD—LOWELL BROOKS, EDITOR, AND PAT BROOKS, BUSINESS MANAGER.

EXPERIMENTS IN ENGINEERING

(Continued from page 22)

possible. It was no longer necessary to assign meaningless laboratory exercises while waiting for the development of theory in another classroom. It became feasible to introduce students to new technical areas with an emphasis on the important experimental problems. When needed, some laboratory time was devoted to assisting students in understanding the theoretical results necessary to carry out the experiment.

Each section has approximately 14 students working in two man groups, and each student had seven contact-hours per week with the same instructor. A further advantage to the separate course concept was that students realized that they were now taking a three hour course, and placed more importance on their laboratory; hence, studying harder for the lab. Also the separate course placed the responsibility on the instructor to create a course which could stand on its own merits and be equivalent to the rest of the E.E. curriculum.

At Syracuse the fundamental criterion in the selection and presentation to the students of a laboratory problem was their concept of student motivation. They believe that the junior-level student possesses an interest in electrical engineering and in some cases is blessed with a measure of intellectual curiosity. The problem therefore were selected to combine experimental work with some theory and technique of measurement, treatment of experimental observations, and occasionally some theoretical analysis. It was felt, that for a student to learn something about scientific laboratory practice, he must at some point have the opportunity to solve an experimental problem in its entirety without specific directions. Obviously this could not be done on the first experiment. Accordingly, the problems were presented as guided projects which became progressively more difficult and required increasing subtly in planning and execution. In every case a significant part of the planning had to be done by the student. For some problems there were a number of alternate acceptable experimental procedures for which equipment was available; for others the alternatives were limited, and the students were required to arrive at one of these solutions with a minimum of guidance.

At the University they were afforded an early measure of student opinion from a survey conducted by a member of the junior class. From

a sample of 27 students, 22 said, "yes," to the question:

"Do you find the electrical engineering laboratory more interesting than the physics lab.?" One answered "no," and for the remainder the question was irrelevant. Although no comment was offered with the negative answer, one student wrote that he was not taking the course and he hoped he never would. Those who found it interesting offered both adverse and favorable comments. Among the reasons for enthusiasm, many students mentioned the flexibility of the project schedule, the emphasis on thought and planning in lieu of rote procedures, and the challenging nature of the problems leading to an atmosphere of research. The reasons are implicit in typical comments such as:

"I am able to work at my own speed, and this enables me to understand what I am doing before I go on."

At the end of the second semester, the staff conducted a student opinion survey. They found that there was a clear preference for those projects which provided an opportunity to use unfamiliar instruments and novel techniques. There was a clear dislike for the projects in which most of the required thinking had been done by the author of the experiment.

Staff reaction to the course was quite good. Instead of trying to avoid laboratory duty if possible, staff members showed an enthusiasm for continuing their present assignments. They gave several reasons for their interest:

- (1) They felt they were doing a better job of laboratory instruction.
- (2) The students seemed to show a genuine enthusiasm for the course.
- (3) They appreciated the projects themselves as challenging scientific problems.

Syracuse feels that they are now doing a good job in laboratory education and are enthusiastic about continuing.⁴

These then, seem to be three fairly new approaches to the problem of creating a suitable course in experimental engineering. They seem to differ from one another however, in execution rather than in their basic philosophy. And they seem to have all shown one basic fact:

The student shows much more interest, works harder, and learns more from a project in which his thinking

(Continued on page 48)

BIG DECISION

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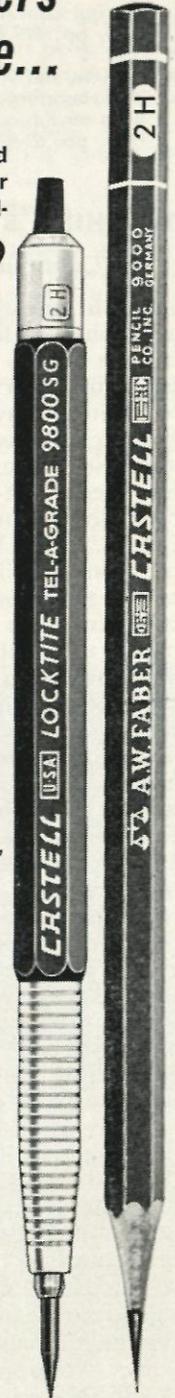
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EXPERIMENTS IN ENGINEERING

(Continued from page 47)

has not been done for him. Contrary to popular opinion, the engineer *does* like to think.

1. Walter J. Fahey, "Undergraduate Laboratories—Some Comments on Efficient Use of a Student's Time," *IRE Transactions on Education*, Vol. E-2, No. 3, June, 1959, pp. 75-78.
2. W. G. Godden, "Models for Teaching Structural Mechanics," *Journal of Engineering Education*, Vol. 53, No. 7, March, 1963, pp. 479-486.
3. *Ibid.*
4. G. Kent and W. H. Card, "An Experiment in Laboratory Education," *IRE Transactions on Education*, Vol. E-4, No. 2, June, 1961, pp. 62-67.

TEACHING BY TELEVISION . . .

(Continued from page 10)

asked in one room may be heard in all rooms in the system. Also located in the Audio control room are a patch bay which enables the operator to connect any source, load, amplifier, etc., to any other source, load, or amplifier, allowing great flexibility for special set-ups or for bypassing breakdowns in the system; and a Gates "Level Devil" expansion-compression amplifier, which is an automatic gain control amplifier which takes an input varying in level by as much as 30 db. or so and increases or decreases its gain in proportion to the level of the input signal to maintain a nearly constant-level output. This amplifier is a great help in maintaining comfortable listening levels throughout a program, as changes in speaking levels of lecturers do not affect their audibility in the classroom. The audio control room is also used as an editing and recording facility for the radio programs produced by the Department, such as Greenway's Primitive Music course offered last semester on one of the Denver radio stations, or the course on Colorado History being produced this semester.

Three courses are presently being presented via instructional television this semester: Educational Psychology, Economics 201, and a graduate Applied Math course being taught in the evenings by Dean Hutchenson. All of these courses are being offered concurrently at the Denver Extension Center, of course, via the microwave relay. Anthropology has also been taught via television in previous semesters. The technique must still be regarded as somewhat experimental; however, experience so far seems to indicate that for the proper subject material properly handled, and with supplementary discussion sections if necessary, ETV can do a significant

service in making the teaching of the outstanding instructor available to more students with no deterioration of the quality of the instruction. Most bias against the method on the part of both faculty and students stems from their unfamiliarity with the system; opinion becomes decidedly less negative as they get used to the method. Future plans call for more classrooms wired for TV, the eventual acquisition of a video tape recorder so that lectures may be recorded for re-showing at a later time, and finally the establishment of an on-the-air service covering about 65% of the state via an educational television station on Channel 12, which has been reserved for educational use in this area by the F.C.C. This service will be another step in the Extension Division's goal to bring better educational opportunities to the people of Colorado.

Anyone interested in learning more about our operation or about educational television in general should feel free to call us at 443-2211 extension 7341 or drop by the studios, Stadium Gate 6, Third floor.

MEASURING TEMPERATURE WITH SOUND

Research engineers have devised a new kind of "thermometer" for taking the ocean's temperature.

The job is done with ultrasonics—sound waves too high in frequency to be audible to the human ear.

Laboratory versions of the ultrasonic thermometer can pinpoint underwater temperatures to five-hundredths of a degree Fahrenheit.

Oceanographers agree that accurate temperature measurement is basic to a better understanding of the ocean depths, now as little known and explored as the environment of outer space. Such physical data are increasingly important. For example, small changes in water temperature are known to critically affect the performance of sonar systems—the "eyes" and "ears" of submarines.

Heart of the new temperature measuring system is an improved type of device, called a transducer, that changes electrical pulsations into mechanical vibrations of ultrasonic frequency. It also can reverse the process, converting the mechanical vibrations into electrical pulses.

The transducer contains a small aluminum disk, about an inch in diameter, which has a natural frequency of vibration of about 40,000 vibrations per second. It is set in motion by a transistorized electronic circuit.

—Westinghouse News

THE SCHROEDINGER WAVE . . .

(Continued from page 19)

pressure variation, or the electric or magnetic fields associated with Maxwell's equations. Ψ , however, does not lend itself to such physically realizable conceptions.

Because the description of Ψ will take either one of two natures corresponding to either quantum or wave mechanics, it might be well to observe an alternate statement for the construction of the two theories as a basis for discussion. The authors of the quantum theory described their theory as the "true theory of a discontinuum" and replaced the classically continuous variables (position and momentum) with systems of discrete numerical matrix quantities, dealing then with processes described in terms of a finite number of dependent variables occurring in a finite number of total differential equations. Schrödinger, as we have seen, chose a "continuous field-like process in configuration space, which is governed by a single partial differential equation."⁵ From these conceptions of the theories we can understand the difference between the significance of Ψ as given by Schrödinger and Born.

Following on his scheme of a continuum and from an analogy with the classical theory of radiation from a system of electrically charged particles where radiation is determined by the electric moment of the system, Schrödinger defines Ψ by describing the product $\Psi^*\Psi$ (which yields the intensity and frequency of radiation) as being "the density of charge, and implies that the system consists of a continuous distribution of charge."⁷ (Here the symbol Ψ^* denotes the complex conjugate of Ψ .) We would infer, from this interpretation, that matter has no particle nature, especially not in the sense of being subject to exact localization in the Schrödinger multidimensional configuration space.

The interpretation most generally dealt with in contemporary literature is that given by Max Born and is related more closely to his quantum mechanics. Here it is assumed that quantum or wave mechanical problems are of a statistical nature and that the product $\Psi^*\Psi$ measures a probability factor. For example, the probability that an electron will be found in the volume element $dx dy dz$ of configuration space is $\Psi^*\Psi dx dy dz$. This analysis leads to another fundamental quantum (wave) mechanical postulate: normalization. Since the particle is certainly somewhere in space, the integral of the function $\Psi^*\Psi dx dy dz$ taken over all configuration space must yield a probability value of one. Adjustment of the coef-

ficient of Ψ' to meet this condition is then the normalization of the wave function.

We are beginning to see that the interpretation of the isolated wave function Ψ' is not physically meaningful, nor in a one-to-one correspondence with the actual behavior of matter, since, in the light of quantum mechanics the intrinsic properties of matter do not exist. Significantly, however, the wave function contains all possible information relating to any system under discussion and describes all the potentialities of the system by assigning a certain probability to each "observable" property. This quality of M is apparent in another of the quantum mechanic postulates: the calculation of the expectation value of the observables $\langle u \rangle$ (position, momentum, energy), where the integral is taken over all configuration space (T).

$$\langle u \rangle = \int_T \Psi^* u (\text{operating on}) \Psi' dT.$$

In view of this, the quantity $\Psi^* \Psi'$ has been called the only contact with the microscopic world available to the macroscopic world.⁸

Finally, it should be pointed out that Ψ and its first derivatives with respect to each of the coordinates of configuration space must be every-

where continuous, finite and single valued to comply with the fundamental postulates.

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LAW AND ENGINEERING . . .

(Continued from page 37)

One of the fundamental questions facing the prospective law school candidates is what the future opportunities in law will be. For the last thirteen years the opportunities open to the young lawyer have been excellent and the competent man will have no trouble in finding a good job. Society is becoming more and more specialized and the need for lawyers can be thought of as being directly proportional to our society's degree of specialization.

An advantage of the law profession is that a large percentage of the lawyers in the United States are in private practice. The self employed lawyer is something like the consulting engineer. Until he has made a reputation, his financial rewards may be meager; but, once established, the rewards are high. Also, the lawyer in private practice is able to derive great satisfaction from establishing his own clientele and from developing his own business.

Thus it appears that the engineer who is more interested in people than in problems and who has enough interest in the humanities to fill the gaps in his education may find a challenging and rewarding career in law.

Acknowledgments

The author wishes to thank Albert R. Menard, Jr., Professor of Law at the University of Colorado for his assistance in preparing this article. The views expressed in this article are the author's.

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Contest Announced . . .

The Gray Iron Founders' Society announced today that 1963 competition in its annual GIFS Design Contest, carrying seven cash prizes for the year's outstanding new designs or redesigns utilizing gray or ductile iron castings, will open May 15. Entries for the contest will be accepted through July 15.

Donald H. Workman, GIFS executive vice president, said engineers, designers, and manufacturers of products and applications making cost-saving, product-improving, or otherwise advantageous use of gray and ductile iron castings are invited to enter into the 1963 competition.

Entries should be mailed anytime between May 15 and July 15, 1963, to Design Contest, Gray Iron Founders' Society, National City—East 6th Bldg., Cleveland 14, Ohio. Entry blanks are available from the Society or from GIFS members.

In addition to cash awards for best entry, second place, and five third place winners, suitable plaques will be presented to winners. Chairman of the 1963 Design Contest judging committee will be William E.

Hoffman, editor of Tooling and Production Magazine, Cleveland. He will head an outstanding panel of impartial judges who will select the contest winners.

Winners will be selected on cost saving, product improvement, significance to the iron foundry industry, and ingenuity of design.

GIFS Design Contest entries should include a description of the new or designed part which utilizes gray or ductile iron, the function of the part and product in which it is used, reasons for using cast iron, comparative cost details of old and new methods of making the part, and advantages resulting from use of cast iron in the design and construction.

Entries should be accompanied by glossy photos, engineering drawing, or rough sketch — preferably photos — and in the case of a redesigned part, before and after photos should be included.

Workman said the Design Contest is conducted by GIFS, national foundry trade association, to stimulate interest in the vast range of design possibilities provided by gray and ductile irons.

COLORADO Engineer

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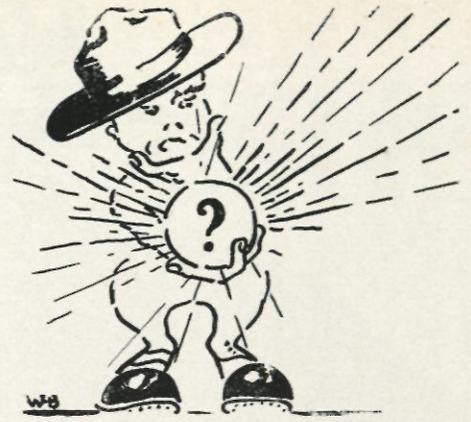
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P U Z Z L E

A G E



MITCHELL ALLIES

Anyone for dueling? Smith, Brown, and Jones, agree to fight a pistol duel under the following unusual conditions. After drawing lots to determine who fires first, second, and third, they take their places at the corners of an equilateral triangle. It is agreed that they will fire single shots in turn and continue in the same cyclic order until two of them are dead. At each turn the man who is firing may aim wherever he pleases. All three duelists know that Smith always hits his target, Brown is 80 per cent accurate, and Jones is 50 per cent accurate. Assuming that all three adopt the best strategy, and no one is killed by a wild shot not intended for him, who has the best chance to survive. It might be interesting to see if you can find the exact survival probabilities of the men. Hint: The answer might be a moral on international politics.

★ ★ ★

A group of airplanes is based on a small island. The tank of each plane holds just enough fuel to take it halfway around the world. Any desired amount of fuel can be transferred from the tank of one plane to the tank of another while the planes are in flight. The only source of fuel is on the island, and for the purposes of the problem it is assumed that there is no time lost in refueling either in the air or on the ground. What is the smallest number of planes that will insure the flight of one plane around the world on a

great circle. It is assumed that the planes have the same constant ground speed and rate of fuel consumption and that all planes return safely to their island base.

SOLUTIONS TO THE PUZZLES IN THE MARCH ISSUE

The locomotive can accomplish the switch and return to its original position in 16 operations:

1. Locomotive moves right, hooks to car A.
2. Pulls A to bottom.
3. Pushes A to left, unhooks.
5. Makes a clockwise circle through tunnel.
6. Pushes B to left. All three are hooked.
7. Pulls A and B to right.
8. Pushes A and B to top. A is unhooked from B.
9. Pulls B to bottom.
10. Pushes B to left, unhooks.
11. Circles counterclockwise through tunnel.
12. Pushes A to bottom.
13. Moves left, hooks to B.
14. Pulls B to right.
15. Pushes B to top, unhooks.
16. Moves left to original position.

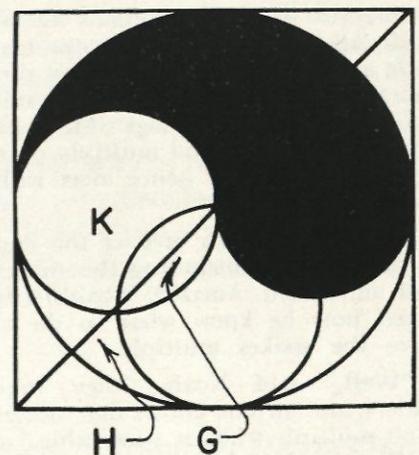
★ ★ ★

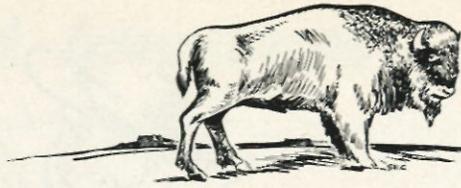
It is not possible for the termite to pass once through the 26 outside cubes and end its journey in the center one. This is demonstrated by imagining that the cubes alternate in color like the cells of a three-dimensional checker board. The large cube will then consist of 13 cubes of one

color and 14 of the other color. The termite's path is always through cubes that alternate in color along the way; therefore if the path is to include all 27 cubes, it must begin and end with a cube belonging to the set of 14. The central cube, however, belongs to the 13 set; hence the desired path is impossible.

★ ★ ★

The monad can be bisected as is shown below. Circle K's diameter is half that of the monad; therefore its area is one-fourth that of the monad. Take region G from this circle, add H, and the resulting region is also one-fourth the monad's area. It follows that area G equals area H, and half of G equals half of H. The bisecting line takes half of G away from circle K, but restores the same area (half of H).





Chips

LARRY HUSTON

Into every life let there come humor.

We have run across some absolutely irrefutable statistics that show exactly why you are tired. And brother it's no wonder you're tired! There aren't as many people actually working as you may have thought. At least, not according to the survey recently completed.

The population of this country is 160 million, but there are 62 million over 60 years of age, which leaves 98 million to do the work. People under the age of 21 years total 54 million which leaves 44 million to do the work.

Then there are 21 million who are employed by the government and that leaves 23 million to do the work. Ten million are in the armed forces, which leaves 13 million to do the work. Deduct 12,800,000, the number in state and city offices, and that leaves 200,000 to do the work. There are 126,000 who are in the hospitals, and that leaves 74,000 to do the work, but 60,000 are bums or vagrants who refuse to work. That leaves 14,000 to do the work. Now it may interest you to know that there are 13,998 in jail, so that leaves just two people to carry the load. That's you and me!

After the flood, Noah sent forth the animals with the admonition, "Each of you multiply, and one year hence meet here to show your accomplishments."

One year later, the animals assembled. All had multiplied except two little snakes. Noah, not the least discouraged, ordered trees to be cut and a table made of the logs. Then he said, "All go forth and multiply once again, and one year hence meet with me here."

When the animals met at the end of the year, all, including the snakes had multiplied. Amazed, Noah's wife asked how he knew what to do to have the snakes multiply.

"Well," said Noah, "they were adders, and anyone knows that adders can't multiply without a log table."

DAFFY DEFINITIONS:

Bridge Game: One place where a wife is always eager to do her husband's bidding.

Conference: A meeting of the bored.

Golf: A long walk punctuated with disappointments.

Happiness: Good health and a poor memory.

Kiss: What the child gets free, the young man steals, and the old man buys.

Optimist: A person who tells you to cheer up when things are going his way.

Pessimist: A person who looks both ways before crossing a one-way street.

Politician: One who shakes your hand before election and your confidence after.

Small Business: A business that never has been investigated by a congressional committee.

Stork: The bird that gets all the blame and none of the fun.

Voluptuous Woman: One who has curves in places where some girls don't even have places.

Wolf: A man who believes in life, liberty, and the Happiness of pursuit.

A few years ago Uranium cost two dollars a ton. Then someone found out it would kill people.

An engineer is said to be a man who knows a great deal about very little and who goes along knowing more and more about less and less until finally he knows practically everything about nothing; whereas,

A salesman, on the other hand, is a man who knows very little about a great deal, and keeps knowing less and less about more and more until he knows practically nothing about everything.

A purchasing agent starts out knowing practically everything about everything, but ends up knowing nothing about anything, due to his association with salesmen and engineers.

We understand that one of the boys over in the EE Department is trying to calculate what the speed of lighting would be if it didn't have to zig-zag.

TOLERANCE is that uncomfortable feeling that the other fellow might be right after all.

Rumor has it that one of our illustrious E.E. Professors is writing a new text on DC machinery. It deals primarily with hot circuits and is entitled Forever Ampere.

The reason the Romans gave up their big holidays was because of the overhead. The lions ate up all the prophets.

Know the difference between a psychotic and neurotic? The psychotic thinks that two-plus two is five. The neurotic knows that two plus two is four—and hates it!

A person who claims that absolute zero is impossible to obtain hasn't taken a quiz in thermo yet.

Little Girl: "Mother, are there skyscrapers in heaven?"

Mother: "No, dear, it takes engineers to build skyscrapers."

Two goldfish in a bowl were talking. They were discussing religion and finally one said in disgust, "But if there's no God, who changes the water every day?"

Anyone who thinks he is indispensable should stick his finger in a bowl of water and notice the hole it makes when he pulls it out.

One can of paint to another: "Darling, I think I'm pigment."

Customer to Bank Teller: "May I see the loan arranger?"

Teller: "He's out to lunch. Would Tonto do?"

A half breed is a man with a cold in one nostril.

This kind of engineer designs jobs instead of things



Once upon a time there was a creature known to jokesmiths as "the efficiency expert." When he wasn't being laughed at, he was being hated. Kodak felt sorry for the poor guy and hoped that in time he could be developed into an honored, weight-pulling professional. That was long ago.

We were then and are much more today a very highly diversified manufacturer. We need mechanical, electrical, chemical, electronic, optical, etc., etc. engineers to design equipment and processes and products for our many kinds of plants, and make it all work. But all the inanimate objects they mastermind eventually have to link up with *people* in some fashion or other—the people who work in the plants, the people who manage the plants, and the people who buy the products. That's why we need "industrial engineers."

A Kodak industrial engineer learns mathematical model-building and Monte Carlo computer techniques. He uses the photographic techniques that we urge upon other manufacturing companies. He collaborates with medicos in physiological measurements, with architects, with sales executives, with manufacturing executives, with his boss (G. H. Gustat, behind the desk above, one of the Fellows of the American Institute of Industrial Engineers). He starts fast. Don Wagner (M.S.I.E., Northwestern '61) had 4 dissimilar projects going the day the above picture was sneaked. He is not atypical. *Want to be one?*

Kodak

EASTMAN KODAK COMPANY • Business & Technical Personnel Department
ROCHESTER 4, N.Y. • An equal-opportunity employer.

An Interview
with G.E.'s
F. K. McCune,
Vice President,
Engineering



As Vice President—Engineering, Francis K. McCune is charged with ensuring the effective development, use and direction of General Electric's engineering talent. Mr. McCune holds a degree in electrical engineering and began his career with the Company as a student engineer.

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How Industry Tempers Theory with Practice to Get Good Design

Q. Mr. McCune, how do you define engineering design?

A. First let's look at what engineering really is. The National Society of Professional Engineers calls it "the creation of technical things and services useful to man." I would paraphrase that to add an industry emphasis: engineering is linking an *ability to do* with specific customer *needs and wants*. The link is an engineering design of a useful product or service.

Q. In the light of this definition, how can the young engineer prepare himself for industry?

A. In college he should absorb as much theory as possible and begin to develop certain attitudes that will help him later in his profession. The raw material for a design, information, flows from three general funds: Scientific Knowledge of Nature; Engineering Technology; and what I call simply Other Relevant Information. Academic training places heavy emphasis on the first two areas, as it should. Engineers in industry draw heavily on theorems, codified information, and significant recorded experience basic to engineering disciplines taught in college. The undergraduate must become knowledgeable in these areas and skilled in the ways of using this information, because he will have little time to learn this after graduation. He also must develop a responsive attitude toward the third fund.

Q. As you say, we learn theory in college, but where do we get the "Other Relevant Information"—the third fund you mentioned?

A. This knowledge is obtained for the most part by actually doing engineering work. This is information that *must* be applied to a design to make sure that it not only works, but that it also meets the needs and wants that prompted its consideration in the first place. For example, we can design refrigerators, turbines, computers, or missile guidance systems using only information from the first two funds of knowledge—heat flow, vibration, electronic theory, etc.—and they will work! But what about cost, reliability, appearance, size—will the prospective customer buy them? The answers to these important design questions are to be found in the third fund; for example the information to determine optimum temperature ranges, to provide the features that appeal to users, or to select the best manufacturing processes. In college you can precondition yourself to seek and accept this sort of information, but only experience in industry can give you specific knowledge applicable to a given product.

Q. Could you suggest other helpful attitudes we might develop?

A. Remember, industry exists to serve the needs and wants of the market place, and the reasons for doing things a certain way arise from the whole spread of conditions which a given design has to satisfy. Learn how to enter into good working relationships with people. Much of the Other Relevant Information can be picked up only from others. Also train yourself to be alert and open-minded about your professional interests. In industry you'll be expected to learn quickly, keep abreast in your field, and to grow from assignment to assignment. Industry will give you the opportunity. Your inherent abilities and attitudes will largely decide your progress.

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