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**COURSES IN PHYSICAL SCIENCE AND
INSTRUMENTATION FOR LIFE SCIENTISTS**

Prepared by: **LESLIE A. GEDDES and
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5-1-66

BIAC

**THE BIOINSTRUMENTATION ADVISORY COUNCIL
of the American Institute of Biological Sciences**

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WASHINGTON, D. C. 20016

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THE BIOINSTRUMENTATION ADVISORY COUNCIL
of the American Institute of Biological Sciences

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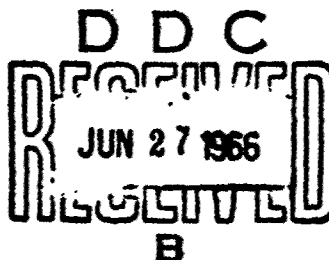
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Gentlemen:

At the request of Mrs. Helen L. Hayes, Head, Oceanic Biology Program, Ocean Science and Technology Group, Code 408/446, Office of Naval Research, I am enclosing copies of BIAC's publications to date.

All future publications will have an acknowledgement to the effect that they have been published under contract to the Office of Naval Research. Our present contract number is Nonr-4526, Task Order 04.

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Sincerely,

Patricia Mitzel
Patricia Mitzel (Mrs.)
Administrative Assistant

PM/t

Enclosures

An Introductory Note: Drs. H. E. Hoff (Chairman, Department of Physiology) and L. A. Geddes (Chief, Biomedical Engineering Section) of Baylor University Medical School have established over the past ten years a remarkable program for teaching the fundamentals of bio-instrumentation to medical students, biologists and engineers. Offered by the Physiology Department, the program is visible in three areas:

- 1- As part of the indoctrination in the regular physiology course for medical students.
- 2- As a six-weeks summer training course in biomedical electronics and basic mammalian physiology for "indoctrinating" researchers in both the physical and life sciences. Now ten years old, this annual course is supported by the National Heart Institute.
- 3- A new year-long program for advanced research people in the bio-sciences which mainly emphasizes applied mathematics, physics and electronics. This program is also supported by the Heart Institute of the National Institutes of Health.

The laboratories which have been developed for these courses are a major reason for the program's success. There are a large number of small unit labs, each accommodating four students, and all equipped with an integrated system of physiological monitoring stations in touch, via a central control console, with neighboring medical facilities as well as each other. Hence the students can at any time witness and participate, through TV and voice links, unusual demonstrations or experiments being carried out. The heart of the student station is the Physiograph Unit, developed by Dr. Geddes, which includes an array of sensors and all of the necessary electronic gear for multiple-monitoring of physiological variables during experiments and operations on small animals. The material which is presented below provides the bare outlines for the two courses plus some notes on the philosophy of the program and the problem of teaching engineering and physics to biological scientists.

I - CLASSICAL PHYSIOLOGY WITH MODERN INSTRUMENTATION

A) Some Notes on the Course

The short course "Classical Physiology with Modern Instrumentation" is a six week's workshop held annually (since 1957) during the months of June and July. The aim of the workshop is to give a basic understanding of the application of modern instrumentation to mammalian physiology. The course includes the fundamentals of design, development and construction of instruments as well as their use in Physiology.

The course is divided into two parts: Physiology and Biophysics. The classical experiments of physiology are performed with particular emphasis on mammalian physiology. The areas covered in the lectures, demonstrations and laboratory assignments are cardiorespiratory, neurophysiology, renal and gastrointestinal. The Biophysics portion covers the fundamentals of electronics, ~~the theory and operation of instruments~~ used in physiology and medicine such as transducers, amplifiers, recorders, power supplies, stimulators, etc. The state-of-the-art of instrumentation in various areas in physiology and medicine are presented from a biophysical point of view. A few of the topics covered are blood pressure and flow, heart sounds, and micro-electrode recording.

COURSE FORMAT

Mornings are devoted to the study of instrumentation, afternoons to Physiology, except that on Fridays, the morning is devoted to a general conference on the week's progress, or review of records, discussion of problems arising, etc. These often develop into wide-ranging general discussions of methods of teaching and research, the philosophy of science, and the wide representation of professional interests and national background made them most interesting indeed. It can be said that everyone participates in these sessions with enthusiasm and they become, unexpectedly and without planning, an important part of the course.

The general attitude adopted in the laboratory is of extreme permissiveness on the one hand, and on the other, a demand for good results and elegant records and preparations. Complicated points are presented in the simplest terms, demonstrations are frequent, but always the students are expected to obtain their own results. Results were discussed on the spot and suggestions made for extension of the experiment. Students are encouraged to try things for themselves once they have mastered the fundamentals of the day's exercise and supplies and assistance are always available to the student with an original idea.

The laboratory is always open, evenings and week-ends, and supplies and animals could be obtained at these times also. The staff makes a point of checking in at these times too, for informal discussion. The laboratory is seldom without a number of students carrying out new experiments, working up records, or discussing their mutual interests.

The exercises in Physiology center around repetition, analysis, and extension of the classical experiments of physiology. Each session begins with a short period devoted to (1) the essential history of the experiment, (2) its importance in Physiology with special consideration of the subsequent work it stimulated and its present status, and (3) the practical advice necessary to attain success. In many cases the experiment is demonstrated in its historical manner. Students then go to their own laboratories, while the demonstration is left in a set-up state for consultation during the afternoon.

The annual field trip to Texas A & M Veterinary College is one of the highlights of the course. On this occasion the classical experiments of Hales, Marey and Chauveau and Claude Bernard are carried out using the horse as the experimental animal, as in the original experiments. Each group is assigned

a task and executes and reports it. All of the reports were collected and edited, and at the termination of the course each candidate receives a bound copy of the studies in experimental physiology carried out on this occasion.

BIOPHYSICS CONTENT

The general aim of this part of the program is to provide the necessary background for an understanding of the instruments used in physiology and medicine. The subject matter is treated in such a way that heavy reliance is not placed on previous training in physics and mathematics. Instead the fundamentals are developed as required and in most cases, elementary algebra and trigonometry are the only mathematics used.

The time allotted to this section of the course (approximately one-half) is divided into daily lecture and laboratory periods. In the lecture periods the fundamental concepts of electronics are developed and whenever possible, practical examples and demonstrations are given to illustrate the various popular instruments such as electrocardiographs, electroencephalographs, electromyographs, vectorcardiographs, blood pressure and flow equipment, heart sound recorders, etc. Each instrument or family of instruments is dissected into its functional sub-units and the units themselves are analyzed. Always kept before the class are the design parameters of the problem and considerable time is devoted to showing exactly how an instrument fulfills its task of faithfully reproducing the physiological event.

A thorough analysis of the physiograph is presented to show the student how functional components were integrated to form a system. However, most emphasis is placed on principle rather than the minute details of interest only to design engineers. Requests for detailed information are answered by sessions with the inquiring individual. Circuit diagrams and mechanical sketches are made available whenever requested by the interested parties. A manual covering complete details of the Physiograph has been prepared and is available for such inquiries.

The laboratory periods (2 hours per day) are designed to accomplish two things. One is to teach the candidates the proper use of tools and electronic instruments; the other is to provide the student with the opportunity to verify the theory presented in the lecture periods. This is accomplished by designing a series of simple but illustrative experiments in which the central point emerges clearly while at the same time exhibiting a practical application of the object of the experiment.

Knowledge of the use of tools and electronic instruments is emphasized in the laboratory assignments. In the first few laboratory sessions, each candidate is given personal supervision to insure the development of good habits which will later be evidenced in good techniques and procedures when carrying out projects designed to use the newly gained knowledge.

The biophysics projects consist of the construction of a piece of equipment from a kit. Each group of two students constructs either an oscilloscope, vacuum tube voltmeter or another device which would be of value in the course in future years. Many complete these assignments in record time and

go on to construct equipment for their own physiological studies. By having equipment always available, every effort is made to permit the candidate to do more than is assigned. More than this, however, the laboratory facilities are placed at the disposal of all of the students day and night and on week-ends so that the candidate may make the most of his time in our laboratories.

INTEGRATING PHYSIOLOGY WITH MODERN INSTRUMENTATION

Because this program of training and investigation relies so heavily on measuring instruments, the philosophy of instrumentation is constantly reviewed. As stated previously, the instruments employed are stressed as essential tools to serve the student. While a few are interested in the minute details of the instruments, most are anxious to develop the "big picture" of the instrumentation system recognizing value and limitations on the one hand and cost and accuracy on the other.

Our views of the role of instrumentation in medicine is most closely described as follows: "Instruments, the indispensable tools of science, are unifying elements which help self-centered disciplines shed their isolationism" wrote Paul Klopsteg in his Presidential Address for the American Association for the Advancement of Science (Science, 1960, 132: 1913-1922). He continued, "To say that instruments with their associated apparatus occupy a place of utmost significance to research, both in advancing basic knowledge and in applying it for human betterment, is to say the obvious. Most research depends profoundly on instruments. Not until an advanced idea, developed by logic into a theory, has been subjected to searching equipment can it attain stability of status. And not until the experiment has been independently repeated and its results confirmed can the theory become assimilated in the body of knowledge. Thus do ideas, forged by logic and theories, and theories, tried and tested with instruments, become science.

"It is noteworthy that among the 138 Nobel laureates in physics and chemistry from 1901 through 1960, this high recognition was accorded 112 of them for research in which instruments were dominant. In the 26 instances of theoretical work, the theories became firmly established by experiment and through successful application in further research. But, conversely, theory was also of key significance in the work of the 112 who were distinguished for superb experimental insight. Clearly, there can be no dichotomy between theory and experiment. Without their interaction, there is no research."

Klopsteg points out how central were measurement of time and distance to the development of early science; indeed how essential these measurements were to non-scientific communications among people: "It may be surmised that the second feeble step in the gradual emergence of science from earliest infancy was taken when man grasped the concepts of time and distance and tried to express them in terms suited to his needs. Such terms, in his world image, lay near at hand, and, with whatever simple system of counting he had, lent themselves to numerical description. Time was probably first identified with the cycle of waking and sleeping and, for longer intervals, with the lunar cycle. Distances were first expressed in dimensions derived from the body, such as arm span, hand span, length of forearm and foot, and pace. Greater lengths could be described by the stone's throw and the arrow shot and, among nomads, by the day's journey.

"If, in truth, early man did find such ways of expressing time and distance, his success probably came not so much from an intellectual quest for definitive knowledge as from efforts to satisfy his need for better communication. Within the implications of this thought is the inference that progress in science depends not solely on measurement. In part, man's earliest efforts to comprehend, in his groping for order and system, probably led to his efforts to confirm his experience with simple experiments. When he had learned to reinforce reason with skill, towards better understanding of his environment, however unsophisticated those first efforts may now seem, he was creating a small base from which to extend his explorations. Measurement, with instruments of special devising, came later."

Indeed, the weights and measures of daily life were the starting points in the evolution of the instruments for the measurement of dynamic processes in science and technology, and still serve as the fundamental basis for calibration. Their value in science is without measure, for as Kelvin wrote, "when you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge of it is of a meagre kind."

In his Idiota of 1450, Nicolaus of Cusa insisted on an intimate relationship between the mind and the art of measurement, alluding to the similarity in their Latin terms when he wrote, "I for my part have a conception that the mind is the bond and measure of all things; and I conjecture it is called 'mens a mensurando,' the mind from measuring." Appropriately he began the dialogue between the learned orator and the not-so-simple Idiot in the marketplace:

Idiot: Because I told thee that wisdom cries out in the streets, and her cry is, that she dwells in the most high places, this now will I endeavor to shew thee. And first tell me what doest thou see here done in the market place?

Orator: I see in one place moneys telling, another wares aweighing, and over and over against us, oyle a measuring, and other things.

Idiot: These are the works of that reason, by which men excell beasts; for bruit beasts can neither number, weigh, nor measure.

In his Address on "The Early History of Instruments of Precision in Medicine" at the Second Congress of American Physicians and Surgeons on September 23, 1891, S. Weir Mitchell wrote of an important by-product of the use of instruments: to sharpen the clinical acumen of the investigator:

"You know, alas! that we now use as many instruments as a mechanic, and that, however much we may gain thereby, our machines are not labour-saving. They force us, by the time their uses exact, to learn, to be rapid, and at the same time accurate. Thinking over the number of instruments of precision, a single case may require, it is clearly to be seen that no matter how expert we may be, the diagnostic study of an obscure case must to-day exact an amount of time far beyond that which Sydenham may have found need to employ. A postmortem section used to take us an hour or two, and now, alas! it goes on for weeks in some shape until the last staining is complete, the last section studied, the last analysis made.

"These increasing demands upon us are due to the use of instruments of precision, or to accurately precise methods. As in factories more and more exact machines have trained to like exactness a generation of workmen, so with us, the use of instruments of precision, rendering the comparison of individual labor possible, has tended to life the general level of acuteness of observation. The instrument trains the man; it exacts accuracy and teaches care; it creates a wholesome appetite for precision which, at last, becomes habitual. The microscope, the balance, the thermometer, the chronograph have given birth to new standards in observation, by which we live, scarce conscious of the change a generation has brought about. Certain interesting intellectual results have everywhere followed the generalisation of precision by the use of instruments, like the world-wide lesson in punctuality taught by the railway and made possible by the watch. We have so often timed the pulse that most of us can guess its rate, and constant use of the thermometer enables one to trust better one's own sense of heat, as the hand appreciates it."

"A good example of the training given by instruments is the fact that a careful study of Harrison Allen's work, with Muybridge's photographs, at last, enables the unaided eye to see in truthful order both the swift changes of convulsive acts and the normal movements of man. The subject is a tempting one and admits of much illustration."

So very central is this association of research and instrumentation to this course that we give a great deal of attention to the philosophy of research and teaching in physiology and to the role of instrumentation.

RETROSPECTIVE COMMENTS

Experience with the course over several years and the careful review of the reports of its participants leads to certain reflections:

The advantage of variety in background of the participants was noted from the first year. Despite widely varied backgrounds, all profited from the course in one way or another, and all felt that they learned much from daily working contact with those from other disciplines. Thus in assigning groups, a point was made to avoid concentrating any one specialty in a single group. Thus it was not unusual to find in any one group a physician, a basic scientist, a dentist, and a physical scientist sharing mutual tasks and effectively teaching each other.

There was a demand for Biophysics by the Graduate Students in this Department and others in the College, so that the Course was incorporated in the Graduate instruction program of the College; and four students enrolled. On conclusion of the course, further instruction was requested and an advanced course was developed for the winter and spring terms.

Most participants paid a considerable price for the course in loss of income or vacation time, and found the original two full months somewhat excessive. In addition, the two-weeks project time held during the first year was somewhat frustrating because they were hardly well started when it was time to stop. For these reasons it seemed wise to shorten the course to six weeks and permit those who wished to remain longer, to work independently after formal conclusion of the course. A number of participants took advantage of this change.

The course was divided into morning sessions in Biophysics and afternoon sessions in Physiology. In both divisions the experimental approach was emphasized; the lectures aimed at presenting fundamental information that could be verified in the laboratory session immediately following. There was therefore a complete correlation of lecture and laboratory. When laboratory exercises could not effectively be assigned, appropriate demonstrations were presented after the lecture. An example was the exposure and deliniation by electrical stimulation of the motor cortex in the monkey, followed by ablation to demonstrate the resulting paralysis.

At the end of each week, record analysis symposia were held. To these sessions the students brought their own records for interpretation and analysis. At this session, and with the facts thus developed, the whole subject was summarized and placed in perspective.

In all cases, before any experiment was performed, it was attempted to make clear why it was important in the historical development of the subject, what it contributed to general present-day knowledge, and how best to reveal it experimentally. In this manner the end-product was brought into focus early in the experiment and aroused a natural curiosity.

The main function of instructors in the laboratory was to interpret the many interesting facets of a problem revealed by the routine multi-dimensional approach, rather than assist the students to obtain results. It is obvious that this is a more challenging and satisfying role for the instructor both from his own and the student's standpoint.

In the construction of equipment period, each student was given an individual task to construct from a kit of parts, one of the standard test instruments which he checked and calibrated and used thereafter. Many of the students elected to purchase these instruments for the cost of components and take with them to their own laboratories.

The Course offered something of value to every participant, but each wanted more information of particular interest to himself. Many expressed an interest in an advanced course.

IMPACT ON CURRICULUM

The training course described in this report served to demonstrate the important role of Biophysics, (now more generally known as Biomedical Engineering) in the measurement of physiological phenomena. The value of this course to the medical school is indicated by the fact that it was given graduate status and is listed as two official courses in the graduate catalog (404 and 405). Other institutions have recognized the value of the course and have sent candidates who took the course for credit which was transferred to and accepted by their own graduate divisions. In our own university, the course is a requisite for all graduate students in physiology and is one of the required courses in the core curriculum for the M.D.-Ph.D. program.

As a direct result of the course, graduate students requested that a continuing course be presented which was tailored to their research needs. Such a course was designed and carries the title "The Measurement of Physiological Events" (421). It is presented each spring and carries a 3 hour credit value.

Another by-product of the course described in this report is the development of joint programs at the Master's level with the schools of engineering at Rice University and the University of Houston. In this program, selected candidates from these institutions are assigned, by joint approval, problems in biomedical engineering on which they carry out their research. Although the degree is obtained from the sponsoring institution, personnel from Baylor Medical College and the sponsoring institution pass on the candidate for his proficiency.

B) COURSE OUTLINE

First Week

LECTURE	INSTRUCTOR'S PERIOD	EXPERIMENT PERIOD	INSTRUCTOR'S PERIOD	EXPERIMENT PERIOD
8:30-9:30 am	9:45-10:00 am	10:00-12:00	1:30-2:45 pm	2:45-5:00 pm
M Introduction & Group Formation	The Measurement of Physiological Events - The Physiograph	Expt. I The Physiograph	Cardiac Muscle	Expt. II Properties of Cardiac Muscle
T Ohm's Law (Direct Current)	Problem Assignment	Expt. I The Measurement of Resistance	Skeletal Muscle	Expt. III Properties of Skeletal Muscle
W Instruments - Voltmeters & Ammeters	Problem Solution Session	Expt. 10 The Wheatstone Bridge	Smooth Muscle	Expt. IV Properties of Smooth Muscle
T Equivalent Circuits- Constant Current & Constant Voltage (Thevenin & Norton)	Use of Tools and Nomenclature of Components	Construction of Kits	Blood Pressure	Expt. V Blood Pressure Parasympathetic Control
F Alternating Currents 1) RMS, Average, Peak 2) Power	Review of Biophysics Experiments	Physiology Record Analysis Session	Blood Pressure	Expt. VI Blood Pressure Sympathetic Control

Second Week

M Vacuum Tube Diode	Introduction to Characteristics of Diode	Expt. 2 Characteristics of the Vacuum Diode	The Electrocardiogram I	Expt. XVII Events of the Cardiac Cycle
T Semiconductor Diode	Introduction to the Characteristics of the Diode	Expt. 9 Characteristics of the Semiconductor Diode	The Electrocardiogram II	Expt. VII The Electrocardiogram & its Relation to Blood Pressure

Second Week - Continued

LECTURE	INSTRUCTOR'S PERIOD	EXPERIMENT PERIOD	INSTRUCTOR'S PERIOD	EXPERIMENT PERIOD
8:30-9:30 am	9:45-10:00 am	10:00-12:00	1:30-2:45 pm	2:45-5:00 pm
W The Triode	Introduction to the Characteristics of the Triode	Expt. 3 Characteristics of the Triode	MARINE PHYSIOLOGY AND FIELD TRIP	
T The Triode Amplifier	Introduction to the Triode Amplifier	Expt. 4 The Triode Amplifier	Heart Sounds	Expt. X Heart Sounds in the Experimental Animal
F The Transistor	Review of Biophysics Experiments	Physiology Record Analysis Session	The Electrocardiogram III	Expt. XV Nature of the Electrocardiogram

Third Week

M The Transistor Amplifier	Introduction to the Transistor Amplifier	Expt. 11 The Transistor Amplifier	Dynamics of the Circulation	Expt. XVIII Pressures in the Cardiovascular System
T Capacitance & Reactance	Introduction to Experiment	Expt. 14 Capacitive Circuits	Atrial Fibrillation	Expt. VIII Atrial Fibrillation
W The Triode Amplifier Low & High Frequency Response	Introduction to the RC Amplifier	Expt. 5 The RC Coupled Amplifier	Ventricular Fibrillation	Expt. IX Ventricular Fibrillation
T	LEGAL HOLIDAY - NO FORMAL CLASSES (Laboratory facilities available)			
F Problem Solution Session	Biophysics Review	Physiology Record Analysis	Fitness Tests	Expt. XIV Heart Sounds, Pulse & ECG in the Human Expt. XXVIII Exercise Tests

Fourth Week

M Inductance & Transformers	Introduction to Experiment	Expt. 15 Inductive Circuits & Transformers	Hemorrhage and Shock	Expt. XIX Hemorrhage and Transfusion
T Impedance and AC Circuits	Introduction to Experiment	Expt. 13 Impedance of Circuits	The Electrocardiogram IV	Expt. XVI The Effect of Ions on the Heart

Fourth Week - Continued

LECTURE	INSTRUCTOR'S PERIOD	EXPERIMENT PERIOD	INSTRUCTOR'S PERIOD	EXPERIMENT PERIOD
8:30-9:30 am	9:45-10:00 am	10:00-12:00	1:30-2:45 pm	2:45-5:00 pm
W Power Amplifiers	Introduction to Experiment VII	Expt. 7 The Transformer Coupled Amplifier	Renal Function	Expt. XII Urinary Flow
T The Push-Pull Amplifier	Introduction to Experiment IX	Expt. 17 The Push-Pull Amplifier	Secretion	Expt. XI Salivary Flow
F Biological Amplifiers	Biophysics Review	Physiology Record Analysis	Respiration	Expt. XX Spirometric Analysis of Respiration

Fifth Week

M Power Supplies	Introduction to Expt. VI	Expt. 6 Power Supplies	Digestion	Expt. XXXII Gastrointestinal Motility
T Fourier Analysis	Demonstration of Fourier Analysis of Complex Waves		Cushing's Law	Expt. XXII Cushing's Law
W Harmonic Analyzers in Medicine	Introduction to Experiment	Expt. 16 Frequency Selective Circuits	Organization of the Central Nervous System	Expt. XXIII Decerebrate Rigidity
T Transient Response	Demonstration of Transient Response	Expt. 12 Sine Wave & Square Wave Response of Amplifiers	The Cortex	Expt. XXIV Decorticate Animal
F Oscillators	Introduction to Experiment VIII	Expt. 8 Relaxation Oscillators	Action Potentials	Expt. XXIX Action Potentials in Nerve & Muscle & Nerve Conduction Velocity

Sixth Week

M Criteria of the Faithful Reproduction of an Event	Review	Make-up Period	The Myoneural Function & the Synapse	Expt. XXXI Myoneural Transmission
T Transduction of Physiological Events	Physiograph, Circuits, Amplifiers and Reproducers	Make-up Period	----	----

Sixth Week - Continued

LECTURE	INSTRUCTOR'S PERIOD	EXPERIMENT PERIOD	INSTRUCTOR'S PERIOD	EXPERIMENT PERIOD
8:30-9:30 am	9:45-10:00 am	10:00-12:00	1:30-2:45 pm	2:45-5:00 pm
W Electrodes - Macro & Micro	Stimulation and Stimulators	The Electrical Activity of the Cortex	Expt. XXX Evoked Cortical Potentials	
T Measurement of Blood Pressure	Measurement of Physiological Events by Impedance	Review	Period	
F BIOPHYSICS	EXAMINATION	PHYSIOLOGY	EXAMINATION	

II - A TRAINING PROGRAM IN APPLIED BIOMEDICAL PHYSICS AND MATHEMATICS

Organization of Course

This training program will consist of formal lectures supported by laboratory periods and research projects. The latter will be organized in the department of Physiology or in other departments with which this department has collaborative programs.

The course will start in September and continue for a full calendar year. The lectures will be presented by fully qualified professors in the areas of their specialty. Some will be presented by faculty members of Baylor Medical College. Others will be given by lecturers drawn from the neighboring institutions, Rice University and the University of Houston; both are in close proximity to Baylor University College of Medicine.

Course Content

The subject matter to be presented lies in three areas: physics, mathematics and bio-electronics. Details of the material are given on the following pages.

The course material has been worked out bearing in mind the needs of the trainee in cardiovascular physiology and his ability to assimilate the subject matter. While the subjects listed might resemble course titles in standard college courses, those in this program are not duplicates of them. The important fundamental principles of each subject have been selected for presentation to the trainees in order to establish a solid base for the problems they are expected to encounter. In every instance the immediate and practical applicability of the material to cardiovascular research will be emphasized in the selection of demonstrations, laboratory exercises and problems; the important interrelations with other systems (nervous, respiratory, endocrine, etc.) will not be neglected.

A typical schedule of lectures and laboratory periods is as follows:

FALL QUARTER

<u>Monday</u>	<u>Tuesday</u>	<u>Wednesday</u>	<u>Thursday</u>	<u>Friday</u>
Math	Physics	Math	Physics	Math
Electronics	Seminar	Electronics	Physics	Electronics
Electronics	Seminar	Electronics	History of Instruments	Electronics
Electronics Lab	Research Project	Research Project	Physics Lab	Research Project

WINTER QUARTER

<u>Monday</u>	<u>Tuesday</u>	<u>Wednesday</u>	<u>Thursday</u>	<u>Friday</u>
Math	Physics	Math	Physics	Math
Electronics	Seminar	Electronics	Physics	Electronics
Electronics	Seminar	Electronics	History of Instruments	Electronics
Electronics Lab	Research Project	Research Project	Physics Lab	Machine Shop
Electronics Lab	Research Project	Research Project	Physics Lab	Research Project

SPRING QUARTER

<u>Monday</u>	<u>Tuesday</u>	<u>Wednesday</u>	<u>Thursday</u>	<u>Friday</u>
Math	Physics	Math	Physics	Math
Electronics	Seminar	Electronics	Physics	Electronics
Electronics	Seminar	Electronics	History of Instruments	Electronics
Transducer Lab	Electronic Devices Lab	Research Project	Computer Lab	Machine Shop
Transducer Lab	Electronic Devices Lab	Research Project	Computer Lab	Research Project

COURSE CONTENT

FALL QUARTER

ELECTRONICS

Coulomb's Law
Electrostatic Fields
Potential
Current Sources
 Batteries, Generators
 Thermoelectric devices
Ohm's Law
Energy and Power
Solution of Circuits
 Kirchoff's Laws Mesh Analysis (Maxwell)
R-L-C Circuits
Q
A-C Bridge Circuits

Wheatstone Bridge
D'Arsonval Movement
 Voltmeter, Ammeter,
 Wattmeter, Ohmmeter
Alternating Current
Complex Algebra
Impedance
Peak and Effective Values of A.C.
Phasor Diagrams
Mutual Inductance
Resonance
Fourier Series
Filters

PHYSICS

Mechanics:

Scalars, Vectors
Statics
Kinetics
 Newton's Laws, Force,
 Acceleration Impulse,
 Inertia, Momentum
Gravitation and Falling Bodies
Work, Energy, Power, Friction
Simple Machines
 Levers, Inclined Plane, Screw,
 Pulleys, Translational Motion
Circular Motion - Central Forces
Rotational Motion
 Moment of Inertia
 Harmonic Motion
Elasticity
 Stress, Strain, Young's Modulus,
 Impact

MATHEMATICS

Algebra:

Numbers
Fractions
Exponentials
Logarithms
Linear Equations
Quadratic Equation
Binomial Theorem
Polynomials

Trigonometry:

Rectangular Coordinates
Polar Coordinates
Trigonometric Functions
Identities
Triangles
Radian Measure

Differential Calculus:

Functions
Increments, Limits
The Derivative
Differentiation of Algebraic and Trigonometric Functions
Interpretation of Derivative
Maxima and Minima Problems
Applications of the Derivative

Hydraulics:

Fluids, Liquids, Gases
Cohesion, Viscosity
Pressure on and within Fluids
Pumps
Archimedes' Principle - Weighing
 Submerged Bodies
Fluids in Motion
 Pressure Gradient, Bernoulli's
 Theorem, Turbulent Flow,
 Reynolds Number, Poiseuille's Law
Surface Tension
Capillarity

Infinite Series

Curve Fitting
Elementary Statistics
Solution of Simultaneous Linear
 Equations
Determinants

Analytic Geometry:

Equation of a Locus
Locus of an Equation
Intercepts
Asymptotes
Range of Values of the Variable
The Straight Line
 Point Slope, Slope Intercept,
 Two Point
The Circle
Conics - Parabola, Hyperbola, Ellipse
Transformation of Coordinates

WINTER QUARTER

ELECTRONICS

Active Circuit Elements:

Vacuum Tubes
Transistors and Other Solid State Devices
Power Supplies
A-C and D-C Amplifiers
Modulation
Detectors
Carrier Systems
Telemetry
Differential Amplifiers

Transient and Steady State Response
Feedback
Oscillators
Sine Wave
Square Wave
Saw Tooth
Multivibrators
Trigger Circuits
Active Filter Elements

PHYSICS

Heat:

Temperature
Ideal Gases
General Gas Law
Heat Measurement
Change of State
Relations between States
Thermal Expansion

The Laws of Thermodynamics
Isothermal and Adiabatic Processes
Diffusion
Osmosis
Propagation
Convection
Conduction
Radiation

Sound:

Transverse and Longitudinal Waves
General Properties of Waves
Refraction, Interference,
Reflection
Huygen's Principle
Production and Transmission
Properties
Intensity, Pitch, Timbre, Beats,
Doppler, Loudness - Weber Fechner
Law, The Decibel, Absorption
Vibrating Strings
Vibrating Membranes
Vibrating Solids
Ultrasonic Principles

Light:

Sources
Propagation
Measurement
Photometry
Properties
Reflection
Refraction
Interference

Light (cont'd):

Lenses
Optical Instruments
Dispersion and Spectra
Diffraction
Polarization
Color
Wien Displacement Law
Quantum
Infrared
Ultraviolet

MATHEMATICS

Integral Calculus:

Rules for Integrating Standard Forms
Definite Integral
Approximate Integration
 Trapezoidal Rule
 Simpson's Rule
Methods of Formal Integration
 Parts
 Partial Fractions
 Substitution
 Reduction Formulas

Differential Equations:

Ordinary Differential Equations
 Order
 Degree
Solution of First Order Linear Equations
Solution of General Linear Second
 Order Equation with Constant
 Coefficients
Applications to Electrical and
Mechanical Systems

SPRING QUARTER

ELECTRONICS

Transducers
 R, L, C
 LVDT
Photodetectors
Hall Effect
Photoelectric
Thermistors
Operational Amplifiers
Rate Meters
Magnetic Tape Recorders
Oscilloscopes
Pen and Light Beam Recorders
Servo Recorders (Plotters)

Stimulators
Specifications for Equipment
 Frequency Response
 Transient Response
 Dynamic Range
Bio-Electric Potentials
Micro Electrode Recording
Macro Electrodes
 Impedance, E-1 Characteristics
 Polarization
Problems Encountered in Coupling
 Commercial Equipment
Applications of Control Theory to
 Biological Systems

PHYSICS

Ionization of Gases
Properties of X-Rays
Applications of X-Rays
Bohr Theory
Quantum Theory
Radioactivity and Isotopes

Nuclear Physics
Nuclear Fission
Astrophysics and Medical Aspects
 of Space Travel
Tracer Methods
Radiation Monitoring

MATHEMATICS

Computers:

Analog Computers
 Applications to Biological Systems
Digital Computers
 Basic Concepts
 Machine Languages and Programming
 Use of IBM 1620-1410

Data Processing:

Probability
Elementary Information Theory
Sampling Theory
Random Processes
Recovery of Information from Noise

MACHINE SHOP PRACTICE

Use of Tools: drill press, taps, dies, milling machine,
lathe, shear, brake, files, grinders.
Processes: plating, painting, heat treating, cementing.
Materials: characteristics of metals, plastics and wood.

SEMINARS

In this program, seminars in the application of physics and mathematics to problems in cardiovascular research will be held. During these sessions, the trainees and their instructors will meet and discuss applications of new knowledge and technology to the solution of problems presented by investigators engaged in cardiovascular and related research. It is here that the necessary mutual interrelation between the physical and biological scientists will be established, and there is reason to believe that this contact will generate a growing collaboration among the scientists involved.

SUMMER QUARTER

RESEARCH

The conduct of research is considered an essential part of this program. In addition to its intradepartmental research activities, the department of Physiology maintains a close liaison with many departments in the medical school. In particular, collaborative programs are now in progress with Surgery, Physical Medicine and Rehabilitation, Medicine (Cardiology), Pediatrics, Urology, Radiology, Neurosurgery, Neurology, Electroencephalography and Veterinary Medicine, the latter at the Texas A & M College of Veterinary Medicine. In all of these areas, well-supervised research opportunities exist for trainees in this program and regular assignment of projects will be made. The summer quarter will be totally devoted to completion of the research.