PHYSICS IN MEDICINE & BIOLOGY ENCYCLOPEDIA

PHYSICS
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Medical Physics, Bioengineering and Biophysics

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Foreword

Medicine and biology advance by revolutions. The nineteenth century saw several, including (in medicine) hygiene, asepsis and anesthesia and (in biology) Darwinism and bacteriology. The first half of the twentieth century saw the rise of chemotherapy, which began when aspirin emerged from the Bayer factory in 1899, reached a climax with antibiotics, analgesics, tranquilizers and hypotensive drugs and now seems to have stabilized. During the same period genetics and biochemistry grew into major scientific disciplines. In parallel with these developments medicine and biology are being increasingly transformed by the incorporation of ideas and techniques derived from physics. The Encyclopedia is a handbook and guide to this new revolution which will, in time to come, be seen as one of the major achievements of twentieth century science and technology.

The origins of this revolution can be traced back to the seventeenth century proposition that science was not merely the theoretical discipline established by the Greeks but could actually be useful to society. Medicine was one of the first proving grounds for this new experimental approach. Enthusiasm was inspired, as always, by the latest scientific advances — mechanics in the seventeenth century and electricity in the eighteenth century. But these early aspirations, even when reinforced by the ingenious craftsmanship of the nineteenth century, did little for the health of the people. It was the union of the intellectual resources of the physical sciences with the abundant technology of the twentieth century that produced the latest, and perhaps the greatest revolution in health care. Since the discoveries of x rays and radioactivity, physicists have been prominent in this movement. Having been recruited since the 1920s to deal with the problem of radiation dosimetry, they were in the right place when the broader opportunities arose — particularly in the climate of increased technological activity generated by World War II. Indeed nuclear medicine grew by the exploitation of measurement techniques based on instruments and methods devised by physicists in the wartime atomic energy projects. The design of the linear accelerators which marked the effective start of supervoltage radiotherapy depended largely on microwave techniques originally used in radar.

The diagnostic and therapeutic uses of ionizing radiation still provide a significant part of the physicist's contribution to medicine. The first major success of computers in health care was in dosage estimation and treatment planning for radiotherapy. More recently the domain of the radiologists has been greatly extended by the incorporation of new imaging techniques, some involving radioactive isotopes and others derived from physics-based techniques including thermography, ultrasonics and nuclear magnetic resonance.

But the uses of radiation no longer dominate medical physics, as they did before the present revolution began. Physicists are now to be found as members of clinical teams in ophthalmology, urology, neurology, neurosurgery, respiratory medicine, medical and surgical cardiology, orthopedics, child health, psychiatry, otology and many other specialities. Clinical chemists have greatly extended their repertoire by the incorporation of techniques such as atomic absorption spectrophotometry, x-ray fluorescence and neutron activation analysis. In the use of these and related techniques, physicists, biochemists and clinicians have made important contributions to the study and control of industrial and environmental hazards in a wider context. Moreover, the physics-based techniques of x-ray diffraction, electron microscopy, radioactive tracers, electronics signal processing and computing have accelerated the progress of biochemistry and physiology and the emergence (out of these two sources) of molecular biology and genetic en-

gineering. In some disciplines, including radiobiology, virology, immunology and pharmacology, medicine and biology have come closely together.

In assembling the text the Editor-in-Chief, Mr Tom McAinsh, has shown great skill and insight in identifying the subjects to be treated and in choosing contributors who have written in a style that is both readable and authoritative. The successful efforts of editor and contributors have produced a work which will be of great interest and value to scientists and engineers working in the realm of medicine, to clinicians in virtually every specialty and to the new generation of biologists. It will be useful also to teachers seeking to illustrate the ideas and methods of physics by reference to biological problems as well as to students of physics and engineering who may be attracted by the prospect of working in the clinical realm and to biologists wishing to secure fuller understanding of the scientific techniques used in their own and adjacent disciplines. An important feature is that contributors have reviewed not only the current situation in their specialized fields but also the scientific foundations on which future progress will be based. The Encyclopedia will therefore be of lasting value as a guide to the development and application of the advances in clinical physics and bioengineering which will have a distinctive influence on the progress of health care in the years ahead.

J. LENIHAN
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Preface

Each of us has an identity that heredity, environment, and circumstance have somehow fashioned. Activity that gives expression to this identity brings particular satisfaction and all the more so if the activity is socially useful and therefore attracts financial support. I enjoy the gaining of understanding — of scientific concepts, processes, and procedures — and the passing on of that understanding to others, and this, I can only assume, is the reason why I have undertaken the sole editorship of an Encyclopedia containing over two hundred articles on diverse medical/scientific topics and written by almost as many authors. There was, of course, from the outset, the additional, obvious if implicit incentive, deeply appealing to a medical physicist, that such work would give much needed publicity to the substantial, present-day involvement of physical scientists in medicine. The public, even the broad scientific community, and certainly the influential politicians and administrators who control public health finances, little realise the importance or the nature of the role of such scientists in health care. They may have a deep and justified respect for the doctors who treat them when they are sick, but somehow they do not connect the technologically sophisticated x-ray equipment, the nuclear medicine apparatus, the lasers, the ultrasound scanners, the clever electronic aids for the handicapped, the fetal monitors, electrocardiographs, and all the other paraphernalia of modern medicine with the engineers and physicists who alone (if the matter is given but a moment's thought) could have designed, built and developed them, or who alone, by virtue of their training and expertise, can ensure their continuing, effective physical use and application.

Such has been the encroachment and impact of high technology in medicine that in many spheres diagnosis and therapy can only be effected by the united efforts of "medics" and scientists, working together in multidisciplinary teams. One of my peripheral hopes for this Encyclopedia is that it will give the reader who is a college undergraduate, or recent graduate, in Physics, or Electronic/Electrical or Mechanical Engineering an insight into the opportunities for interesting, useful and gainful activity that a career in medicine provides.

I should explain how the Encyclopedia came about and how it grew within the framework of the institution in which I have spent my own career as a medical physicist, the West of Scotland Health Boards' Department of Clinical Physics and Bio-Engineering. The Department is the largest organization of its kind in the world, having a present staff complement that includes 90 graduate physicists and engineers, and 130 fully qualified medical physics technicians. It is a regional department. Thus, while some of the staff work in the central laboratories in the heart of Glasgow, most perform their daily tasks in teams in a variety of clinical and diagnostic departments in hospitals throughout the West of Scotland, serving a total population of some three million. Further, although the Department is primarily a branch of the National Health Service it has staff based in many professorial departments of the Faculty of Medicine of Glasgow University. It was to Professor John Lenihan, who until his retirement in Septe ıber 1983 was Director of the Department of Clinical Physics and Bio-Engineering and Professor of Clinical Physics at Glasgow University, that Pergamon Press initially turned for help and advice on a Physics and Medicine in Biology Encyclopedia. Professor Lenihan subsequently recommended me to Pergamon Press as Editor, having overcome my initial "swithering" (a good Scottish word, meaning "to hesitate over a decision") by referring to the substantial support I could expect from my numerous and knowledgeable colleagues.

Both Professor Lenihan and Professor Joe McKie who succeeded Professor Lenihan in office in 1983, and indeed the entire Department, have maintained a friendly and constructive interest in the Encyclopedia throughout the period of its preparation. As the reader may have observed, Professor Lenihan has kindly written the Foreword. Several of my eminent colleagues have

contributed articles as have many friends and associates who work in various departments at Glasgow University, including the Beatson Institute for Cancer Research, and in the Bioengineering Unit of the University of Strathclyde, Glasgow's other University. If these contributions have added a certain Scottish flavour to the Encyclopedia, may its pages bring its readers that incomparable sense of illumination, stimulation and enlightenment that one associates (so I am informed) with a "taste of Scotland".

In compiling the Encyclopedia my intention has been to provide a comprehensive and convenient source of enlightenment for individual hospital physicists, medical technologists, and clinicians who wish to be informed on any of the numerous, important topics of which they themselves have little or even no knowledge but which nevertheless provide routine activity for their fellow professionals who work in other university and hospital departments. Each article is therefore written for the reader who has a basic grounding in physics, but no particular knowledge of the topic under discussion — whatever his knowledge or distinction in his own field, be it medical or scientific. Because the Encyclopedia is aimed essentially at the novice, it will make excellent reading for college students who are studying science or medicine, the bibliographies and reference lists associated with each article pointing the way to deeper study and involvement. I would emphasise, nevertheless, that the Encyclopedia is neither a training book nor a text book. For this reason, and having regard to the wide readership for which the Encyclopedia is intended, I have, in the main, omitted topics which by their very nature would necessitate a highly mathematical treatment. On the other hand because many of the articles included are predominantly clinical in nature (not a few have been written by eminent physicians and surgeons) a glossary has been added for the benefit of readers who are students or practitioners of physical science and who may have scant knowledge of anatomy, physiology, and pathology.

The topicality of the Encyclopedia is, of course, an important consideration, and I have therefore included techniques which have recently blossomed in importance, such as the clinical applications of nuclear magnetic resonance spectrometry, digital fluorography, Doppler techniques for measuring blood flow, and the use of heavy ions and mesons in radiotherapy. Medical imaging in its theoretical and its practical aspects is broadly discussed, and in all its modes — computerized axial tomography, nuclear magnetic resonance, ultrasound scanning, positron emission tomography and radionuclide imaging in general. Topics which continue to provide bread-and-butter activity for hospital physicists have not been forgotten: conventional radiotherapy in all its aspects, radiology, radioactivity measurement, and protection from the possible hazards of ionizing and other types of radiation. Also represented are topics which hospital physicists in small hospital departments are unlikely to encounter in their day-to-day work. These include activation analysis, spectroscopy and chromatography in forensic medicine, physics in dentistry, electromyography, communication aids for the physically handicapped, and radiopharmaceuticals preparation, to name but a few. Finally, research topics such as radiobiology, membrane physics, cell electrophoresis, x-ray diffraction in molecular biology, electron microscopy, bioelectricity and genetic engineering have been included, since it is essential to gain a deeper understanding of the processes which underlie disease if diseases are to be conquered rather than, at best, treated and contained.

My foremost duty as Editor as I conceive it, has been to represent the interests of the reader. Books, after all, are for readers, as hospitals are for patients. In retrospect I realise that as Editor I have been an "impedance matcher", optimizing the flow of information from writer to reader and minimizing the amount of heat and vexation generated at the interface! In this connection, I owe a specific debt of gratitude to several of the Encyclopedia's distinguished contributors. All of them are specialists in their own field. Many are authors of books; almost all are regular contributors to the professional literature. They are mainly accustomed, however, to writing for their peers. Writing for the reader whom I have been wont to call the "intelligent ignoramus" can pose particular problems. If a lady in the course of a conversation refers to her son's German mistress she will possibly have emphasised the word "German", or perhaps those to whom she speaks

know, either from her previous remarks or from knowledge otherwise gained, that her son is a twelve-year old, not unusually precocious schoolboy who is studying the German language. I tell this little tale to illustrate how easy it is for the reader who does not have the benefit of background knowledge to misinterpret or even fail to understand what might appear, prima facie, a clear, simple and unambiguous statement. This is a condition which I am sure we all remember from our student days. Incidentally, it is somewhat alarming how easily a simple omission, say, of a comma, or a particular placement of a phrase or clause in a sentence, or a perhaps unfortunate choice of preposition or conjunction, can impede communication. On those occasions when I have sought confirmation of an interpretation — from one of my many local experts — it has been interesting to note how, in not a few instances, they fail to see what the problem is, at least at a first reading. Their minds, have been conditioned to "lock on" to a particular interpretation — in their case, the correct one. As I have indicated, I am extremely grateful to those contributors — for their understanding and forbearance — who have allowed me, with their approval, to rearrange their material. I hope that my interceding in this way has been to the benefit of the reader. It may also have conferred a certain uniformity of style to the Encyclopedia.

It remains for me to thank all who in one way or another have assisted in the evolution and production of the Encyclopedia. I am grateful to have been supported by the distinguished members of the Honorary Editorial Board and I thank them in particular for their constructive advice and recommendations a propos the final compilation of articles. I would acknowledge, too, in the same respect, the helpful and constructive criticisms and suggestions of Dr Dick Mould, of the Westminster Hospital, London. I remember, too, the help of my colleague, Dr R C Lawson and that of Professor P W Horton, Professor of Medical Physics, University of Surrey, England, in preparing the initial compilation. I would thank, also, J Stewart Orr, Professor and Director of Medical Physics, Hammersmith Hospital, London, Dr N C Spurway, Senior Lecturer in Physiology, University of Glasgow, and my colleague Dr T E Wheldon, who all were characteristically helpful in introducing me to many notable and appropriate authors. Many of my colleagues have put their expertise at my disposal — the names of Dr Aled Evans, Dr A T Elliott, Dr D J Mackinnon and Dr R G Bessent come particularly to mind. Of course, I owe a special debt of gratitude to Dr Bill Martin for his excellent Index. My thanks, also, to Mrs Jeanette Mackinnon who somehow deciphered and typed my editorial scribblings. And I would acknowledge once more my indebtedness to the Department of Clinical Physics and Bio-Engineering, to its former Director, Professor John Lenihan, and to its present Director, Professor Joe McKie particularly for his kind support and interest in the latter period of the Encyclopedia's preparation.

I have, of course, to thank the Publishers, Pergamon Press, who have made it all possible. One of the most pleasant aspects of my task has been my association with the hard working copy editors of Pergamon's Encyclopedias group. Salutations therefore to Mr Peter Strickland, Miss Debbie Puleston, and colleagues. It has been a particular privilege, too, to have been associated with Pergamon's Managing Editor, Encyclopedias, Dr Philip Maxwell. Dr Maxwell's conscientious professionalism and single-minded dedication to the job-in-hand is outmatched, I have observed, only by his remarkable and unfailing politeness to everyone with whom he deals.

And, finally, my thanks to my dear wife, Muriel, who surely must be the most patient listener in all the world.

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Classified List of Articles

The Classified List of Articles groups the contents of the Encyclopedia by article title into a number of broad fields, alphabetically organized, from Audiology to Vision. The reader is thus presented with a general overview of the contents of the Encyclopedia. Some articles inevitably relate equally well to more than one heading. Rather than make an arbitrary decision as to which section they belong, each article has been listed wherever appropriate. For example, "Computers in Neurology" is listed under both "**Computers in Medicine**" and "**Neurological Sciences**."

The main topics covered are:

Audiology

Acoustic Impedance Audiometry; Artificial Ear; Artificial Mastoid; Audiometers; Brain-Stem Electric Response Audiometry; Ear Anatomy and Physiology; Electric Response Audiometry; Electrocochleography; Electrodermal Audiometry; Electroencephalic Audiometry; Hearing Aids; Objective Audiometry; Sound: Biological Effects; Speech Spectrography

Biomaterials and Biomechanical Engineering

Artificial Joints, Implanted; Artificial Limbs and Locomotor Aids: Evaluation; Artificial Membranes; Biomechanics; Bone: Mechanical Properties; Dental Force Analysis; Dental Materials; Gait Analysis; Heart Valves; Implanted Prostheses: Tissue Response; Mechanical Devices in Medicine and Rehabilitation; Prostheses, Myoelectrically Controlled; Soft Connective Tissues: Mechanical Behavior

Biophysics

Animal Calorimetry; Bioelectricity; Biological Control Theory; Biometry; Biophysics; Cryobiology; Cybernetics, Biological; Decision Theory; Hormesis and Homeostasis; Hypothermia; Mathematical Modelling in Biology; Muscle; Thermodynamics, Classical

Blood

Blood Cell Analysis: Automatic Counting and Sizing; Blood Cell Analysis: Morphological and Related Characteristics; Blood Flow: Invasive and Noninvasive Measurement; Blood Gas Analysis; Blood Gas Tensions: Continuous Measurement; Blood Pressure: Invasive and Noninvasive Measurement; Blood Viscosity Measurement; Doppler Blood Flow Measurement; Hemodynamics; Plethysmography; Thrombosis

Cardiology

Ambulatory Monitoring; Cardiac Catheterization; Cardiac Function: Noninvasive Assessment; Cardiac Output Measurement; Cardiac Pacemakers: Computerized Data Handling; Cardiac Pacemakers, Implantable; Cardiac Pacemakers, Temporary; Computers in Cardiology;

Defibrillators; Dynamic Cardiac Studies; Echocardiography; Electrocardiography; Heart Valves; Heart–Lung Machines; Intra-Aortic Balloon Pumps; Monitoring Equipment in Coronary and Intensive Care; Vectorcardiography

Computers in Medicine
Biological Kinetics: Computerized Data Analysis; Cardiac Pacemakers: Computerized Data Handling; Computer-Aided Diagnosis; Computerized Axial Tomography; Computerized Image Analysis in Radiology; Computers in Cardiology; Computers in Clinical Biochemistry; Computers in Neurology; Microcomputers; Microcomputers: An Application in the Clinical Laboratory

Gastroenterology, Nephrology and Urology
Endoscopes; Fiber Endoscopy; Renal Dialysis; Renal Function: Diagnostic Measurement; Urology: Fluid Flow and Pressure Measurement

Imaging
Cerebral Blood Flow: Regional Measurement; Computerized Axial Tomography; Computerized Image Analysis in Radiology; Digital Fluorography; Dynamic Cardiac Studies; Image Analysis: Receiver-Operating-Characteristic Curves; Image Analysis: Transfer Functions; Image Analysis: Extraction of Quantitative Diagnostic Information; Mammography; Neutron Radiography; Nuclear Magnetic Resonance Imaging; Positron Emission Tomography; Radiography and Fluoroscopy in Medicine; Radionuclide Imaging; Radionuclide Brain Imaging; Scanning Electron Microscopy; Single-Photon Emission Tomography; Thermography; Transmission Electron Microscopy; Ultrasonic Image Analysis; Ultrasound in Medicine; Ultrasound in Obstetrics

Laboratory Techniques
Blood Cell Analysis: Automatic Counting and Sizing; Blood Cell Analysis: Morphological and Related Characteristics; Centrifuges: Principles and Applications; Cervical Cytology: Automation; Chromatography; Chromosome Analysis, Automatic; Clinical Biochemistry: Automation; Clinical Chemistry: Physics and Instrumentation; Colorimetry; Computers in Clinical Biochemistry; Electron Microprobe Analysis; Electron Microscopy: Freeze-Fracture Replication; Fluorimetry; Forensic Applications of Chromatography; Forensic Applications of Spectroscopy; Microcomputers: An Application in the Clinical Laboratory; Microphotometry; Neutron Activation Analysis; Particle-Induced X-Ray Emission Analysis; Photon Activation Analysis; Radioimmunoassay; Scanning Electron Microscopy; Spectroscopy; Transmission Electron Microscopy

Mathematics in Medicine and Biology
Biometry; Biological Control Theory; Biostatistics; Cancer Statistics; Decision Theory; Image Analysis: Transfer Functions; Mathematical Modelling in Biology; Signal Analysis Techniques; Statistical Methods in Medicine

Molecular and Cell Biology
Cell Electrophoresis; Cervical Cytology: Automation; Chemical Carcinogenesis; Chromosome Analysis, Automatic; Genetic Code; Genetic Engineering; X-Ray Diffraction in Molecular Biology

Neurological Sciences
Cerebral Blood Flow: Regional Measurement; Computers in Neurology; Electroencephalography; Electromyography; Evoked Potentials; Intracerebral Electrodes; Intracranial Pressure Measurement; Neurosurgery: Physiological Monitoring; Radionuclide Brain Imaging; Radionuclide Cisternography; Visual Cortical Neurophysiology

Nuclear Magnetic Resonance
Nuclear Magnetic Resonance: General Principles; Nuclear Magnetic Resonance Imaging; Nuclear Magnetic Resonance Spectroscopy

Nuclear Medicine
Beta-Particle Detection; Cerebal Blood Flow: Regional Measurement; Cyclotrons; Dosimetry of Internally Administered Radioactive Substances; Dynamic Cardiac Studies; Gamma-Ray Detectors; Neutron Sources; Nuclear Medicine Department Design and Equipment; Occupancy Principle; Phantoms in Nuclear Medicine; Positron Emission Tomography; Quality Assurance in Nuclear Medicine; Radiation Quantities and Units; Radioactivity Measurement; Radioactivity Measurement: Counting Statistics; Radioiodine: Clinical Uses; Radionuclide Brain Imaging; Radionuclide Cisternography; Radionuclide Generators; Radionuclide Imaging; Radionuclides: Clinical Uses; Radionuclides: Whole-Body Monitors; Radiopharmaceuticals: Preparation and Quality Assurance; Renal Function: Diagnostic Measurements; Single-Photon Emission Tomography

Physics in Dentistry
Dental Diagnosis; Dental Enamel: Crystallography; Dental Fluoridation; Dental Force Analysis; Dental Materials; Preventive Dentistry; Teeth: Electron Microscopy Studies; Teeth: Physical Properties

Physiological Measurement and Monitoring
Ambulatory Monitoring; Biotelemetry; Blood Flow: Invasive and Noninvasive Measurement; Blood Gas Analysis; Blood Gas Tensions: Continuous Measurement; Blood Pressure: Invasive and Noninvasive Measurement; Blood Viscosity Measurement; Cardiac Catheterization; Cardiac Function: Noninvasive Assessment; Cardiac Output Measurement; Cerebral Blood Flow: Regional Measurement; Clinical Temperature Measurement; Doppler Blood Flow Measurement; Echocardiography; Electrocardiography; Electrocochleography; Electroencephalography; Electromyography; Electrooculography; Electroretinography; Evoked Potentials; Fetal Monitoring; Intracerebral Electrodes; Intracranial Pressure Measurement; Medical Gases: Measurement and Analysis; Medical Photography; Monitoring Equipment in Coronary and Intensive Care; Neonatal Intensive Care Equipment; Neurosurgery: Physiological Monitoring; Neutron Activation Analysis *In Vivo;* Photogrammetry; Physiological Measurement; Plethysmography; Recording and Display Devices; Renal Function: Diagnostic Measurement; Respiratory Function: Physiology; Respiratory Function: Methods of Assessment; Respiratory Function Measurement: Equipment; Signal Analysis Techniques; Space Biology and Physiology; Thermography; Urology: Fluid Flow and Pressure Measurement; Vectorcardiography

Radiobiology
Cell Population Kinetics; Microdosimetry; Radiation Carcinogenesis; Radiation Chemistry; Radiobiology: Charged and Uncharged Particles; Radiobiology: Kinetic Basis of Normal-Tissue Response to Radiation; Radiobiology: Prenatal and Perinatal Irradiation; Radiosensitizers; Target Theory and Repair Models in Cellular Radiobiology; X Rays: Biological Effects

Radiology
Computerized Axial Tomography; Computerized Image Analysis in Radiology; Digital Fluorography; Mammography; Neutron Radiography; Quality Assurance in Diagnostic Radiology; Radiography and Fluoroscopy in Medicine; Radiography and Fluoroscopy in Phonetics; Speech Spectrography; X-Ray Production; X Rays in Medicine: Early History

Radiotherapy
Brachytherapy; Cancer Statistics; Electron Linear Accelerators; Fast Neutron Therapy; Hyperthermia in Cancer Treatment; Ionizing Radiation: Absorption in Body Tissues; Neutron-Capture Therapy; Neutron Dosimetry; Neutron Kerma Values; Radiation Dosimetry; Radiation Quantities and Units; Radiation Quantities: Measurement; Radiosensitizers; Radiotherapy: Afterloading Techniques; Radiotherapy: Beta Particles; Radiotherapy: Cobalt Treatment; Radiotherapy: Computer-Aided Treatment Planning; Radiotherapy: Heavy Ions, Mesons, Neutrons and Protons; Radiotherapy: Isodose Charts; Radiotherapy: Linear Accelerators; Radiotherapy: Radiation Dose, Time and Fraction Number Formulae; Radiotherapy: Treatment Planning; Radium in Medicine: Early History

Respiratory Physics
Anesthesia Physics; Medical Gases: Measurement and Analysis; Respiratory Function: Physiology; Respiratory Function: Methods of Assessment; Respiratory Function Measurement: Equipment

Safety in Medicine
Medical Electrical Equipment: Safety Aspects; Nonionizing Electromagnetic Radiation: Potential Hazards; Radiation Protection and Personnel Monitoring; Radiation Protection: External Exposure; Radiation Protection: Internal Exposure; Radioactive Waste Disposal: Hospital Practice; Radio-Frequency and Microwave Radiation: Potential Hazards; Sound: Biological Effects; Static Electricity in Hospitals; Ultrasound: Potential Hazards; Ultraviolet Radiation and the Skin; Ultraviolet Radiation: Potential Hazards

Therapeutic Aids and Techniques
Biofeedback; Cardiac Pacemakers: Computerized Data Handling; Cardiac Pacemakers, Implantable; Cardiac Pacemakers, Temporary; Communication Aids for the Physically Handicapped; Cryobiology; Defibrillators; Electric and Magnetic Fields: Biological Effects; Electroconvulsive Therapy; Electrosurgery; Endoscopes; Fiber Endoscopy; Hearing Aids; Heart–Lung Machines; Hyperbaric Medicine; Intra-Aortic Balloon Pumps; Lasers in Medicine; Laser Physics; Mechanical Devices in Medicine and Rehabilitation; Nebulizer Therapy; Prostheses, Myoelectrically Controlled; Renal Dialysis; Ultraviolet Radiation and the Skin

Ultrasonics
Doppler Blood Flow Measurement; Echocardiography; Ultrasonic Image Analysis; Ultrasound in Medicine; Ultrasound in Obstetrics; Ultrasound: Potential Hazards; Ultrasound Therapy; Ultrasound: Tissue Characterization; Ultrasound: Transmission and Scattering in Human Tissue

Units
Radiation Quantities and Units; Radiation Quantities: Measurement; SI Units

Vision
Binocular Vision; Color Blindness; Color Vision; Electrooculography; Electroretinography; Intraocular Fluid Dynamics; Vision; Visual Cortical Neurophysiology; Visual Fields and Thresholds

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