PRNC 17

PUERTO RICO NUCLEAR CENTER

PROGRAM OF INSTRUCTION
FOR PRNC REACTOR OPERATORS

(Academic Phase)

PROGRAM OF INSTRUCTION

FOR

PUERTO RICO NUCLEAR CENTER

REACTOR OPERATORS

(Academic Phase)

BY

HECTOR BARCELO

SECTION I - PREFACE

A.	COURSE	:	PRNC REACTOR OPERATORS COURSE (Academic Phase)
B.	PURPOSE	:	To provide reactor operator trainees with the academic preparation necessary for further technical instruction in the operation and maintenance of PRNC research reactors.
C.	PREREQUISITES	:	Admission to the PRNC Reactor Operators Training Course
D.	LENGTH	:	6 months
E.	TRAINING LOCATION	:	Puerto Rico Nuclear Center - Mayaguez

SECTION II - SUMMARY

PRNC REACTOR OPERATORS COURSE (Academic Phase)

Time: 6 months

Subject	Hours	Annex	Page
Academic Subjects			
Mathematics and Slide Rule	71	1	4
Physics	61	2	11
Nuclear Engineering	66	3	15
Electro-Mechanical Engineering	96	4	21
Health Physics and Chemistry	39	5	27
Plant Information	21	6	30

Type of Instruction

Lecture	L
Demonstration	D
Conference	C
Practical Exercise	PE
Examination	E

SECTION III - BODY

FRNC REACTOR OPERATORS COURSE (Academic Phase)

ACADEMIC SUBJECTS

Time: 354 hours

SUBJECT	SCOPE	ANNEX	HOURS	PAGE
MATHEMATICS	Algebraic operations; algebraic equations; logarithms and exponentials; trigonometry and vectors; slide rule; J operators; examinations.	1	71	4
PHYSICS	Basic mechanics, work, power, and energy; atomic physics and radioactivity; basic radiation detection; nuclear physics; examination. Laboratories.	2	61	11
NUCLEAR ENGINEERING	Reactor physics; steady state analysis; transient analysis; reactor engineering; reactor operation; advanced systems; examination, laboratories.	3	66	15
ELECTRO-MECHANICAL ENGINEERING	D.C. circuits; A.C. circuits; transformers; motors; protective equipment; electronics; examination, laboratories.		96	21
	Basic fluid dynamics and pumps; power plant components; materials and practices; basic thermodynamics; examination; laboratories.			
HEALTH PHYSICS AND CHEMISTRY	Effects of ionizing radiation; standards of radiological protection; applied health physics; chemistry and feedwater treatment; examination; laboratories.		39	27
PLANT INFORMATION	Introduction and general plant features; primary systems; secondary systems; examination and laboratories (plant tours).		21	30

SECTION IV - ANNEXES

ANNEX NUMBER 1

Mathematics and Slide Rule

Time: 71 hours

PURPOSE: To give the student mathematical ability in basic arithmetic operations, algebra, trigonometry, vectors, logarithms; to teach students slide rule operations required for the solution of applied problems in other academic subjects.

	SUBJECT	SCOPE	HOURS AND TYPE
1	Course Introduction	Introduction to subject; use of literal numbers; definition of algebraic terms and notations; terms and factors; signs of grouping.	1 L
2	Arithmetic Functions I	Review of methods in addition, subtraction, multiplication of arithmetic functions; simplification of complex fractions; operations with positive, negative numbers, with zero.	1 L
3	Slide Rule I	Introduction to the slide rule; Reading the slide rule - "C" and "D" scales; "C1" and "DL" scales.	1 LPE
4	Laws of exponents	Laws of addition, subtraction, multiplication, and division of exponents.	1 L
5	Radicals	Definitions; conversion from exponential to radical form; factoring and removal of factors from the radical; addition, subtraction, multiplication of radicals.	1 L
6	Slide Rule II	Simple multiplication on the "C" and "D" scales. "C1" and "D1" scales. Ratio and proportion involving "C" and "D" scales.	1 PE
7	Exponents and radicals	Practical exercise involving materials covered in hours 4 and 5.	1 PE

	SUBJECT	SCOPE	HOURS AND TYPE
8	Multiplication of monomials and	Multiplication of positive and negative numbers; multiplication of monomials and polynomials.	1 L
9	Slide Rule III	Multiplication of numbers involving the use of powers of ten.	1 LPE
10	Multiplication of monomials and polynomials	Practical exercises and review of material covered in hour No. 8.	1 PE
11	Division of Monomial and	Division of monomials and polynomials by monomials and polynomials.	1 L
12	Slide Rule IV	Division involving use of "C", "D", "C1" and "D1" scales use of ratio and proportion and power of ten.	1 LPE
13	Division of Monomials and Polynomials	Practical exercises and review of material covered in hour No. 11.	1 PE
14	Special Products and Factoring I	Squaring binomials; product of sum and difference of two terms; product of any two binomials.	1 L
15	Special Products and Factoring II	Factoring polynomials with common factors, difference of two squares, various trinomials, sum and difference of two cubes.	1 L
16	Special Products and Factoring III	Practical exercises and review of material covered in hours No. 14 and 15.	1 PE
17	Fraction Reduction I	Reduction of literal fractions and mixed expressions by lowest common denominator.	1 L
18	Fraction Reduction II	Addition, subtraction, multiplication and division of literal fractions; complex fractions.	1 L
19	Fraction Reduction III	Practical exercise in reduction of fractions.	1 PE
20	Dimensional Analysis I	Introduction to dimensions and dimensional systems both English and Metric.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
21	Dimensional Analysis II	Practical exercises and review of material covered in hours No. 20 and 21.	1 LPE
22	Review Class	Review of material covered in hours No. 1 to 21.	1 CF
23	Examination I	Examination on material covered in hours No. 1 to 21.	1 E
24	Slide Rule V	Combined operations of multiplication and division involving "C", "D", "C1" and "D1" scales and powers of ten.	1 LPE
25	Linear Equations I	Definitions; equations, indentities and conditional equations axioms in operations with equations; rules of transposition, cancelling, changing of signs.	1 L
26	Linear Equations II	Checking of equations, practical exercise in the solution of linear equations.	1 PE
27	Slide Rule VI	Use of "A", "B" and "K" scales on slide rule.	1 LEP
28	Graphs of Equations I	Principles of graphics; rectangular coordinate system; intercept and slope; solutions of simultaneous linear equations.	1 L
29	Graphs of Equations II	Practical exercises and review of material covered in hour No. 28	1 PE
30	Slide Rule VII	Raising any number to any power. Using LL and LLO scales. Comparison with "A", "B", and "K" scales.	1 L
31	Simultaneous Linear Equations - I	Algebraic solution by addition and subtraction; substitution; and comparison methods.	1 L
32	Simultaneous Linear Equations - II	Solution of equations containing three unknowns.	1 L
33	Simultaneous Linear Equations - III	Practical exercises in solutions of equations with two and three unknowns.	1 PE

	SUBJECT	SCOPE	HOURS AND TYPE
34	Fractional Equations	Solution of fractional equations.	1 L
35	Radical Equations	Solution of radical equations.	1 L
36	Quadratic Equations	Solution of quadratic equations.	1 L
37	Fractional Radical and Quadratic Equations	Practical exercise in the solution of fractional, radical and quadratic equations.	1 PE
38	Literal Equations I	Solution of literal equations similar to those encountered in other academic courses.	1 L
39	Literal Equations II	Practical exercises and review of material covered in hour No. 38.	1 PE
40	Review	Review of material covered in hours No. 24 to 39.	1 CF
41	Examination II	Examination on material covered in hours No. 24 to 40.	1 E
42	Trigonometry Definitions	Introduction to trigonometry definition of angle; coordinate system; measurement of angles similar right triangles.	1 L
43	Trigonometric Functions I	Definition of basic functions; reciprocal functions of the same angle; co-functions of the complementary angle. Basic definitions of functions of any angle.	1 L
44	Trigonometric Functions II	Functions of the common angles within the circle.	1 L
45	Trigonometric Tables	Use of tables and slide rule to find the function of the angle. Discussion of how the sine, cosine, tangent vary through the use of the unit circle.	1 L
46	Slide Rule VIII	Use of the slide rule involving the sine and cosine scales.	1 LPE
47	Slide Rule IX	Use of the slide rule involving the tangent scales.	1 LPE

	SUBJECT	SCOPE	HOURS AND TYPE
48	Right Triangles	Solution of the right triangle.	1 L
49	Slide Rule X	Solution of the right triangle on the slide rule.	1 LPE
50	Periodic Functions I	Rotation of the unit circle; graphs of the trig. functions.	1 L
51	Periodic Functions II	General sine wave equation; angular motion; oscillatory motion; rotary motion.	1 LPE
52	Review Class	Review of material covered in hours 42 to 51.	1 CF
53	Examination III	Examination on material covered in hours 42 to 51.	1 E
54	Logarithms I	Definition of logarithm use in multiplication, division, and raising to power.	1 L
55	Logarithms II	Base 10 logarithms; mantissa and characteristic.	1 L
56	Logarithms III	Practical exercise involving material covered in hours 54 and 55.	1 PE
57	Slide Rule XI	Practical exercises in use of "L" scale.	1 LPE
58	Logarithms	Base "e" logarithms; finding natural logs using "LL" scales on slide rule.	1 LPE
59	Slide Rule XII	Slide rule proficiency test.	1 PE
60	Exponential Equations	Solution of logarithmic and exponential equations. Graphs of logarithmic functions; solutions of growth and decay relationships.	1 L
61	Graphs of Functions I	Advantages of semi-log and log-log graph paper and comparison to linear plot. Plotting of e^{x} and e^{-x}.	1 L
62	Review Class	Review of material covered in hours 54 to 61.	1 CF
63	Examination IV	Examination on material covered in hours 54 to 61.	1 E

	SUBJECT	SCOPE	HOURS AND TYPE
64	Plane Vectors I	Definitions; emphasis on notation; addition of vectors.	1 L
65	Plane Vectors II	Vector subtraction; components of a vector, addition of rectangular components.	1 L
66	Plane Vectors III	Solution of vector problems.	1 PE
67	j Operator I	Real and imaginary numbers; complex numbers; graphical representation of numbers affected by j; fundamental operations with complex numbers.	1 L
68	j Operators II	Graphical representation of addition subtraction, multiplication and division of complex numbers; polar form of complex numbers, multiplication and division of complex numbers in polar form.	1 L
69	j Operator III	Practical exercise involving material covered in hours 67 and 68.	1 PE
70	Review Class	Review of material covered in hours 64 to 69.	1 CF
71	Examination V	Examination in material covered in hours 64 to 70.	1 E

ANNEX NUMBER 2

PHYSICS

Time: 61 hours

PURPOSE: To provide students a basic understanding of the classical and nuclear physics necessary for a detail study of nuclear reactor engineering and health physics.

	SUBJECT	SCOPE	HOURS AND TYPE
1	Introduction and CGS system	Course importance, objectives procedures, CGS units of mass length, time, force, work, and power.	1 L
2	Linear Motion	Velocity-time-distance relationship, acceleration, gravity, momentum and force.	1 L
3	Rotary Motion	Radion, angular velocity, and acceleration.	1 L
4	Force, work and power.	Review motion, force, work, power, units, equivalence of work and energy change.	1 L
5	Energy I	Explanation and comparison of all forms of energy; KE and PE, formula and units; identification with particles; relationship to work.	1 L
6	Energy II	Heat energy and temperature, theory, units, temperature scales and conversions.	1 L
7	Energy III	Electric energy, electrostatic force and potential, reference to EE, electron properties.	1 L
8	Energy IV	Chemical and nuclear energy, comparison of energy release, reaction equations, and magnitudes.	1 L
9	Examination I	All materials from 1 to 8.	1 E
10	Matter and Molecules	Properties of water including states, density, composition, division of water into molecules compounds and mixtures.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
11	The Atom	Identification of elements, chemical symbols and periodic table; electrons, protons and neutrons; electrostatic forces.	1 L
12	Models of the Atom	Models of Thompson, Rutherford, Bohr, Bohr Summerfield, Hyperfine, and Modern.	1 L
13	Atomic Number and Mass	Relationship to number of protons, electrons 2 x 4 mass of natural atoms, isotopes, isobars, isomers nuclear reaction equation.	1 L
14	Mass Equivalent of Energy	Einstein's equation, calculations amu to ev conversion, nuclear reactions equations.	1 L
15	Mass Defect and Binding Energy	Mass of constituents vs. mass of resultants; relationship of BE to mass defect; release of BE, BE per nucleon.	1 L
16	Examination II	All materials from 11 to 16.	1 L
17	Radioactivity I	Introduction to radioactivity, both natural and artificial; properties of radiation.	1 L
18	Radioactivity II	Demonstration of physical phenomena.	1 D
19	Radioactive Decay	Statistics of radioactive decay, half life, decay constant, laws of exponential decay.	1 L
20	Chart of the Nuclides	Use of Chart of Nuclides in radioactive decay and nuclear reactions.	1 L
21	Radioactive Decay Series	Parent-daughter decay series, natural and artificial series.	1 L
22	Alpha and Beta Particles	Charge and mass; typical alpha and beta decay; range in air; equation; energy; neutrino.	1 L
23	Gamma Rays and Neutrons	Charge and mass; other electromagnetic radiation; range; wave length; frequency, Planck's constant, energy.	1 L
24	Interactions of Particles	Ions' electrostatic attraction and repulsion; specific ionization vs. pathlength; electron-volt.	1 L
25	Interaction of Radiation with Matter	Photo-electric effect, Compton scattering, pair production; annihilation radiation.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
26	Detection I	Principles of operation of ionization chamber, proportional counter.	1 L
27	Detection II	Principles of operation of UIC, CIC, BF detector, and fission chamber.	1 L
28	Radiation Attenuation I	Time and distance; radioactive decay, inverse square law.	1 L
29	Attenuation by Materials	Material effect on attenuation, attenuation coefficient; energy and material dependence; half thickness.	1 L
30	Review	All material from 19 to 29	1 C
31	Examination III	All material from 19 to 29	1 E
32	Interactions of Neutrons with Matter	Review properties of neutrons; absorption, scattering, fission.	1 L
33	Flux	Beam flux; reactor flux; concept, units, relation to intensity.	1 L
34	Reaction Cross Section I	Dependence of cross section on projectile energy; target nucleus, and specific reactions.	1 L
35	Reaction Cross Section II	Microscopic and Macroscopic cross sections.	1 L
36	Reaction Rate	Dependence on flux and microscopic cross section; sample calculation.	1 L
37	Non-fission absorption of neutrons	Conditions leading to non fission absorption; activation; applicability to reactors.	1 L
38	Neutron Moderation	Elastic and inelastic scattering; conservation of momentum and KE; necessity of moderation, properties of moderators; physical events during moderation.	1 L
39	Fission Process	Conditions leading to fission; liquid drop model; threshold energy; the fissionable nuclides used in reactors.	1 L
40	Neutron Physics	Review physical events during moderation; introduction to neutron lifetime, fermi age diffusion length, migration area.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
41	Examination	All material covered in 1 to 40	2 E
42	Boyle's Law and Charles' Law	Behavior of gases under varying conditions; introduction to lab. procedures and graphing experimental results.	
43	Statistical Nature of Radioactivity	Use of scalers, and determination of desintegration probabilities of radioactive sources.	4 PE
44	Radiation Measurements	Use of G.M., proportional counters, scintillation and BF_3 detectors. Voltage plateau determination.	4 PE
45	Radioactive Decay	Determination of half-life and decay constant.	4 PE
46	Gamma Shielding	Shield effectiveness of various materials; attenuation coefficients	4 PE

ANNEX NUMBER 3

NUCLEAR ENGINEERING

Time: 66 hours

PURPOSE: To give the student an understanding of the basic nuclear reactor theory and related fundamental procedures essential for a detailed study of plant operations.

	SUBJECT	SCOPE	HOURS AND TYPE
1	Fissionable Materials	Introduction. Names and symbols of prime fissionable materials; fuel enrichment.	1 L
2	Fission Process and Chain Reaction	Liquid-drop nuclear model; conditions required for fission; release of energy in fission; fission product distribution. Chain reaction: non-sustaining, sustaining, multiplying.	1 L
3	Neutron Cross Sections and Reaction Rate I	Review reaction rates; microscopic and macroscopic cross sections; units; fission and capture cross sections of reactor materials.	1 L
4	Neutron Cross Sections and Reaction Rate II	Practical exercise in the use of reaction probabilities and cross sections.	1 PE
5	Fission Neutrons	Neutron energy spectrum; prompt and delayed neutrons; decay of delayed neutron precursors. Definition of beta, the delayed neutron fraction.	1 L
6	Neutron Generation Time and Lifetime	Neutron lifetime; effective neutron generation time; the effects of delayed neutrons upon overall generation time; influence upon reactor control.	1 L
7	Neutron Travel	Derivation of average logarithmic energy decrement; moderator slowing down power, moderating ratio; fermi age, slowing down length; diffusion length; migration area, migration length.	1 L
8	Infinite Multiplication	Definition of k_{oo}, the multiplication factor. Introduction to the four factor formula. Calculation of four terms from the neutron cycle.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
9	Neutron Production and Fast Fission	Definition and derivation of reproduction factor; dependence of eta upon fuel enrichment; definition of fast fission factor; dependence of epsilon upon enrichment, ratio of fuel to moderator, and other reactor parameters.	1 L
10	Resonance Escape and Thermal Utilization	Definition of resonance escape probability; control of p through moderator/fuel ratio, fuel absorption cross section, average logarithmic energy decrement of moderator, enrichment; definition and derivation of thermal utilization factor, influence of moderator/fuel ratio.	1 L
11	Fast and Thermal Leakage	The finite reactor; definition of k_{eff}. Definition and mathematical expression of fast and thermal neutron nonleakage probabilities; solution of materials buckling.	1 L
12	Geometric Buckling	Geometric buckling; relationship between materials and geometric buckling; sample calculation of core critical size.	1 L
13	Examination I	Examination on material covered from 1 to 12.	1 E
14	Multiplication I	Review of multiplication factor. Derivation of neutron multiplication equation; sample calculations.	1 L
15	Multiplication II	Derivation of neutron multiplication equation; discussion of equation assumptions and limitations; review of effective neutron generation time.	1 L
16	Multiplication III	Definition of reactor period. Derivation of neutron multiplication equation definition of reactivity; graph of reactivity vs. period; relationship between reactivity and effective neutron generation time.	1 L
17	Reactivity Coefficients I	Temperature coefficients of reactivity; nuclear coefficients due to changes in diffusion length, fermi age, nuclear cross sections, and doppler effects; density coefficients due to changes in macroscopic cross sections, buckling, and reactor dimensions.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
18	Reactivity Coefficients II	Pressure, void and poison coefficients of reactivity; effects upon reactor operation; fuel loading requirements to compensate for negative reactivity effects.	1 L
19	Poisons I	Origin of fission product poisons; qualitative and mathematical description of the rate of buildup and removal of xenon poison; equilibrium concentration.	1 L
20	Poisons II	Mathematical derivation of the reactivity equivalent of reactor poison from the influence of poisons upon thermal utilization factor. Sample calculations.	1 L
21	Control Rod Effects	Effect of control rods; perturbation of reactor flux; use of control rods to compensate for negative reactivity effects and changes in power; shadowing effects; introduction to rod worth.	1 L
22	Transient Effects	Review of transient analysis; multiplication equations, reactor period, reactivity and reactivity coefficients, flux perturbation; delayed neutron transients.	1 L
23	Examination II	Examination of material covered from 14 to 22.	1 E
24	Flux Control	Types of control rods; general features of reactor control; scrams, backsets interlocks; function of the operator.	1 L
25	Reactor Instrumentation	Types and ranges of reactor flux monitoring instruments; uses during operation; start-up; linear power, log n, period and power channels, principles of design.	1 L
26	Control Rod Worth	Review of principles of Control rod worth; experimental procedure for worth determination; sample calculations.	1 L
27	Reactivity Coefficients	Experimental procedure for determination of temperature and poison coefficients; sample calculations.	1 L
28	Reactor Fuel Elements	Types and functions of reactor fuel elements; fabrication principles; burnable poisons.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
29	Heat Transfer I	Principles of heat transfer; conduction, convection, radiation; temperature versus heat transfer curves; nucleate boiling.	1 L
30	Heat Transfer II	Reactor heat sources; dependence upon flux, hot spots; shutdown heat sources, removal of decay heat.	1 L
31	Reactor Management	Reactor accident conditions; scram parameters and bypasses; design considerations; maximum credible accident; radiation hazards in plant location and safety.	1 L
32	Examination III	Examination on material covered from 24 to 31.	1 E
33	Reactor Shielding	Review of particle and ray attenuation; types and effectiveness of shielding materials; removal of heat from shield.	1 L
34	Reactor Materials I	Types of reactor coolants; characteristics of various coolants; selection criteria; moderating and reflecting materials.	1 L
35	Reactor Materials II	Reactor structural materials; other materials associated with reactor components; corrosion, mass transport.	1 L
36	Reactor Materials III	Radiation effects upon reactor materials, activation; nul-ductility transition temperatures; curves of operating limits.	1 L
37	Reactor Loop Components	Components peculiar to reactor systems; piping requirements zero leakage pumps and valves; leakage control systems; purification systems.	1 L
38	Subcritical Multiplication	Derivation of mathematical expression for neutron subcritical multiplication; significance of multiplication; reactor neutron sources; startup procedures.	1 L
39	Core Loading	Core loading procedures; inverse multiplication curves, significance, application to loading of fuel storage areas.	1 L
40	Startup Operations	Approach to criticality; startup procedures; hazards involved in improper operation.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
41	Power Operation and Shutdown	Reactor operation at power; important system parameters; shutdown conditions; review of nuclear reactor engineering.	1 L
42	Examination IV	Examination on material covered from 33 to 41.	2 E
43	Neutron Phenomena	Demonstration covering moderation, reflection, diffusion, and other neutron phenomena.	4 PE
44	Introduction to Nuclear Simulator	General introduction to nuclear simulator, operation of simulator, and description of components.	3 PE
45	Reactor Startup	Familiarization with reactor startup procedures and transient behavior during startup.	3 PE
46	Reactivity vs. Period	Effects of radioactivity changes on reactor period, graphing reactivity vs. period curves.	3 PE
47	Control Rod Calibration	Reactivity worth calibration of control rod.	3 PE
48	Poison Effects on Reactivity	Effects of Xenon and other poison on reactivity.	3 PE
49	Core Loading	Core loading procedures, inverse multiplication.	3 PE
50	Automatic Controls	Requirements for automatic controls, demonstration of controllers and stability operation.	3 PE

ANNEX NUMBER 4

ELECTRO-MECHANICAL ENGINEERING

Time: 96 hours

PURPOSE: To give the students an understanding of electric circuits found in electrical and electronics fields and to provide the students with some understanding of fluid flow and heat transfer and of components found in nuclear reactors.

	SUBJECT	SCOPE	HOURS AND TYPE
1	The Simple Electric Circuit	Outline of course; Ohms Law, power, sample problems.	1 L
2	D C Series Circuits	Kirchoff's voltage law, application of Ohm's and Kirchoff's laws to D C series circuits.	1 L
3	D C Parallel Circuits	Kirchoff's current law, application of Ohm's and Kirchoff's laws to D C parallel circuits.	1 L
4	D C Compound Circuits	Series-parallel combinations, simplification and solution of compound circuits, voltage dividers.	1 L
5	D C Circuit Problems	Student solution in class of D C circuit problems.	1 PE
6	Electrical Conductors	Wire measurement, resistivity, insulation, protection.	1 L
7	Review of DC Theory	Examination on material covered from 1 to 6.	1 E
8	Alternating Current	AC definitions, vectors, sine wave characteristics.	1 L
9	Inductance	Self inductance, induced emf, mutual inductance, phase relations, time constant.	1 L
10	Capacitance	Capacitor construction, dielectrics, time constant, phase relations.	1 L
11	Inductive and Capacitive Reactance	Phase relations between voltage current in reactive circuits, vector problems; impedance.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
12	AC Power	True power, reactive power, apparent power, power factor, power triangle.	1 L
13	AC Series Circuits	Solution of series circuits containing resistance, inductance, and capacitance.	1 L
14	AC Parallel Circuits	Solution of parallel circuits containing resistance, inductance, and capacitance.	1 L
15	AC Compound Circuits	Solution of compound circuits with complex branches.	1 L
16	AC Circuit Problems	Students solve AC problems in class.	1 PE
17	Basic Electrical Indicating Instruments	D'Arsonval galvanometer, ammeter, voltmeter, shunts and multipliers, electrodynamometer.	1 L
18	Review of AC Theory	Review of all material covered in 8 to 17.	1 C
19	Examination II	Examination on material covered in 8 to 17.	1 E
20	Tubes and Current Conduction	Tube types; electron emission.	1 L
21	Unidirectional Devices	Vacuum diodes, crystal diodes, dry disk rectifiers.	1 L
22	Power Supplies	Purpose, components, filters, waveforms.	1 L
23	Power Supply Waveforms	Demonstration of half and full wave rectification with various filters.	1 D
24	Amplification in Vacuum Tubes	Fundamentals of vacuum triode amplifiers.	1 L
25	Gas-Filled Tubes and Synchros	Gas diodes, thyratrons, phototubes, application of synchro devices to rod drive indicators.	1 L
26	Review	Review of electronics from 20 to 25.	1 C
27	Examination III	Examination on material covered from 20 to 25.	1 E
28	Transformers	Theory of operation, construction, efficiency.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
29	Transformer Applications	Instrument transformers, power and distribution transformers, autotransformers.	1 L
30	Transformer Connections	Single and three phase hookups polarity, polyphase windings.	1 L
31	Low Voltage Protective and Switching Equipment	Short circuits, overcurrents, fuses, switches circuit breakers, distribution systems.	1 L
32	Review of EE	Review of all material covered from 1 to 31.	1 C
33	Examination IV	Examination in material covered from 1 to 31.	2 E
34	Fundamental Concepts of Mechanical Engineering	Outline of course; symbols and English system of units; force, work, energy, power, efficiency, and torque. Physical properties of liquids and gases.	1 L
35	Pressure	Pressure; definition, absolute, gage, atmospheric, vacuum and concept of pressure head.	1 L
36	Pressure Measurement	Pressure measuring devices; open manometer, differential manometer, barometer, Bourdon gage.	1 L
37	Fluid Flow	Description and calculation of flow. Pressure, velocity, head.	1 L
38	Bernoulli's Equation	Pressure, velocity, and flow measuring devices. Bernoulli's equation. Pump and friction heads.	1 L
39	Application of Bernoulli's Equation	Application of Bernoulli's equation to solve practical problems by students in class.	1 L
40	Evaluation of Friction Losses	Fluid friction in pipes; laminar flow; Reynold's number. Friction losses in valves and fittings.	1 L
41	Evaluation of Pump Work	Determination of pump horsepower required for various piping systems. Practical problems.	1 L
42	Pumps	Classification of pumps by types and groups. Head and flow relations in pumps.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
43	Review	Review of material covered in 34 to 42.	1 C
44	Examination I	All material covered in periods 34 to 42.	1 E
45	Temperature Measurements and Effects of Heat	Review temperature heat relationship; Centigrade, Fahrenheit, Kelvin temperature scales and conversion. Nature of heat. Linear, differential area and volume expansion and contraction of liquids and solids.	1 L
46	Heat Measurement	Definitions; British thermal unit, thermal capacity, specific heat. Application of fundamental heat equation.	1 L
47	Heat Transfer-Conduction	Heat transfer by conduction. Principle of conduction and the influencing factors. Practical problems.	1 L
48	Convection	Heat transfer by forced and natural convection and influencing factors.	1 L
49	Radiation	Heat transfer by radiation and influencing factors.	1 L
50	Thermodynamics	The mechanical equivalent of heat. The laws of thermodynamics. Thermodynamics systems. Introduction to general energy equation.	1 L
51	General Energy Equation	General energy equation; potential and kinetic energy, transferred heat, external work. Application of the equation.	2 L
52	Examination II	All material covered in periods 45 to 51.	1 E
53	Feedwater Equipment	Classification of heat exchangers, purposes, types and construction of deaerators and evaporators.	1 L
54	Auxiliary Equipment	Purpose, operation and construction of valves; gate, globe, check, safety, characteristics of piping and fittings.	1 L
55	Nuclear Power Equipment	General requirements and features of water cooled nuclear reactors. Pumps, valves, piping and heat exchangers.	1 L
56	Corrosion and Course Review	Definition, types, causes and prevention. Specific application in reactors. Review of entire course.	1 C

	SUBJECT	SCOPE	HOURS AND TYPE
57	Examination III	All material covered in ME course.	2 E
58	Introduction Measuring Resistance and Power in DC circuits	Identification, safe handling, connections of equipment and instruments. Measurement of resistance and power using voltmeter ammeter, wheatstone bridge, ohmeter, and wattmeter.	4 PE
59	D.C. Circuits	Series and parallel DC circuits, verification of Kirchoff's current and voltage laws. Additional practice in interpreting and hooking up electrical circuits.	4 PE
60	Single Phase AC circuits	Demonstration on oscilloscope lagging and leading currents as inductance and capacitance are varied in an RCL network. Measurement of effect of inductance and capacitance independently on current voltage relationship. Impedance measurement.	4 PE
61	Power in A.C. Circuits	Measurement of power in AC circuits using wattmeters. Determine power factor in AC circuits. Draw vector relationships.	4 PE
62	Rectification	Investigation of the characteristics of halwave and fullwave rectifiers. Comparison of filter networks.	4 PE
63	Transformers	Read and interpret wiring diagrams of single, parallel transformer connection. Polarity check of transformer. Three phase transformer connections, voltage and current checks, effect of unbalance.	4 PE
64	Introduction to ME Laboratory	Laboratory techniques; basic exercises and computations in density, specific gravity, pressure vacuum and fluid flow rates.	4 PE
65	Fluid Flow	Use of mercury differential manometer; determination of resistance to flow in gate and globe valves.	4 PE
66	Characteristic Pump Curves	Nature, importance, and use of characteristic curves; obtaining head vs. flow, efficiency and horse power curves. Comparison of pump types; centrifugal and rotary.	4 PE

ANNEX NUMBER 5

HEALTH PHYSICS AND CHEMISTRY

Time: 39 hours

PURPOSE: To give the students background in the principles and purpose of Health Physics and Water Chemistry; a working knowledge of personnel protection, monitoring equipment, basic chemistry, feedwater treatment and related analysis, and general procedures followed in research reactors.

	SUBJECT	SCOPE	HOURS AND TYPE
1	Introduction	Administrative details; introduction to health physics; early discovery and experience with radiation; development of health physics; comparison and application to nuclear field.	1 L
2	Ionizing Radiation	Review of atomic structure and composition; origin of radiation emission; interaction of particles with matter; effects of ionization from various types of radiation.	1 L
3	Radiation Units I	Radioactive decay-physical and biological definitions of roentgen, curie, rep, rad, rem, and R.B.E.	2 L
4	Radiation Units II	Problem solving; practical work with units; curies, rep, rad, rem and R.B.E. Use of nomographs.	1 PE
5	Biology	Characteristics of living things; cells, tissues, organs, organ systems; components of cells-(genes and chromosomes)- principal organs of interest in humans.	1 L
6	Biological Effects	Physical, chemical, biological and physiological effects of radiation; acute and chronic exposures; external and internal hazards; radio-sensitivity of body organs.	1 L
7	Maximum (external) Permissible Concentrations	Limits for external radiation exposure; limiting exposure by time, distance and shielding.	2 L
8	M. P. C. (external)	Calculation of working times in external radiation fields with and without shielding.	1 PE
9	M. P. C. Internal	Limits for internal radiation hazards; critical organs; air and water activity limits.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
10	Examination I	Examination of lessons 1 to 9.	1 L
11	Activity Analysis I	Sampling procedures; air, water, sampling preparations; counting techniques.	1 LD
12	Activity Analysis II	Activity determinations, counting statistics (interpretation of).	2 LD
13	Radiation Hazards and Control in Reactors	Sources of radiation hazards; concept of control-delineation of areas; radiation work permit; personnel and equipment decontamination.	1 L
14	Personnel Monitoring and Protection	Requirements for film badges and pocket dosimeters, survey and personnel monitoring equipment; protective clothing-use and availability. Responsibility for use of this equipment.	1 LD
15	In-Plant Monitoring and Control	Control of radiation areas; monitoring of areas and effluents; area radiation monitoring systems; control of sources and radioactive materials.	1 L
16	External Plant Controls	Concepts of environmental monitoring; radioactive waste storage and disposal; shipment of radioactive materials definition of accidents and incidents, general procedures.	1 L
17	Responsibilities of Individuals in Nuclear Plants Relative to HP	Responsibilities of Health Physicist, supervisors, and individuals; the Health Physicist in the chain of command; reports and records.	1 L
18	Examination II	Examination of lessons 1 to 17.	1 L
19	Basic Chemistry	Principles, theory, ionization, acids and bases.	1 L
20	Feedwater Treatment and Analysis	Water and its impurities, aeration, coagulation, filtration, demineralization; PH, conductivity.	3 LD
21	Material Balance	Theory of material balance and problems.	1 L
22	Examination III	Feedwater treatment, chemistry, material balance.	1 E

	SUBJECT	SCOPE	HOURS AND TYPE
23	Survey Instruments	Principle of operation of detectors and survey instruments used for alpha, beta, gamma and neutron detection; point and area surveys. Calibration of instruments. Construction of calibration curves.	4 PE
24	Area Survey	Use of previously calibrated instruments to survey a radiation area. Setting up of access controls and determination of working times at specified locations in the area.	4 PE
25	Feedwater Treatment	Demonstration and practical exercise on water aeration, handouts, coagulation, filtration, demineralization, pH, conductivity, Cl, SO_3 and O_2 analysis.	4 PE

ANNEX NUMBER 6

PLANT INFORMATION

Time: 21 hours

PURPOSE: To familiarize students with the design and function of the system, components, general hardware and safety of nuclear plants as ground work in preparing the student for Plant Operations Training. It is intended that this course will show the students how the theory he has learned in other academic subjects ties in with actual plant design.

	SUBJECT	SCOPE	HOURS AND TYPE
1	Instrumentation	General description of primary instrumentation, nuclear instrumentation, and where located, method of control by control rod drives, and primary system temperature measures.	2 L
2	Primary System Instrumentation	System and components used to measure temperature, flow and level.	1 L
3	Nuclear Instrumentation	Problems encountered in detection, types of detectors, and the source range, power range channels.	1 L
4	Control Rod Drive System	Functions, design considerations, construction of control rod drive mechanisms; together with the sources of power, interlocks and associated instrumentation.	1 L
5	Reactor Protective Systems	Ways of controlling a reactor during operation, design requirements of a control rod system, types of control rods (shim and safety), conditions which could cause damage (loss of coolant, loss of flow and reactivity addition).	2 L
6	Operational Aspects of Water Chemistry	Sampling of primary and secondary water, what is analyzed for, what is expected or required limits and what corrective action is used. Methods of chemical addition blowdown, various methods of water chemistry control.	1 L
7	Shielding	Discussion of primary and secondary shielding construction, materials, shadow shielding using plant components and shield water cooling system.	1 L

	SUBJECT	SCOPE	HOURS AND TYPE
8	Refueling	Discussion of general refueling procedures, tools and precautions.	1 L
9	Examination	Examination of material covered from 1 to 8.	1 E
10	Reactor Safety Requirements	AEC regulations and organization. Analysis of hazards evaluation and what may be found therein.	1 L
11	Core Design Reports and History of Nuclear Incidents	Discussion of what data is available from core design reports from contractors and a discussion of the more prominent nuclear incidents, including overdosages to scientific personnel.	1 L
12	Tour of PRNC Reactors	Tour of the PRNC swimming pool reactor to point out important system components.	4 PE
13	PRNC Tour	Detailed tour of the PRNC swimming pool reactor pointing out details of systems and instrumentation.	4 PE