Appendix III – Department Guide to Reason and Enlightenment (DGRE)

Department Guide to Reason and Enlightenment

(DGRE)

PC2013 INTRODUCTORY APPLIED PHYSICS LABORATORY (3-4)

A. CATALOG DESCRIPTION: This course is an introduction to basic electronic test instrumentation and basic passive and active circuit components, with emphasis on extensive, practical hands-on exposure to laboratory hardware and devices. Included are the measurement and signal processing of analog signals and analog sensors/ transducers. Operational amplifiers are introduced as building blocks of analog systems. Passive LRC filters and active filters are studied with an emphasis on applications. Some background in laboratory instrumentation and simple DC and AC circuit elements is assumed. Prerequisite: College-level basic physics and mathematics, plus simple electrical circuits (e.g. PH1322).

B. RECOMMENDED TEXT: TBD

C. COURSE CONTENT:

1. Analysis of linear circuits and mesh networks. Voltage dividers. Idealized voltage and current sources. Thevenin's and Norton's theorems and their practical utility. Applications of complex numbers to sinusoidal signals; complex impedances. Complex transfer functions. Review of passive LRC filters, filter transfer characteristics and Q factor. Laboratory introduction to DMMs, power supplies, function generators and oscilloscopes.
2. Introduction to semiconductor physics. Conduction in semiconductors. Physics of p-n junctions. Characteristics of the p-n junction diode. Full and half-wave rectifiers. Photodiodes, light-emitting diodes, and Zener diodes.
3. Introduction to the physics of the bipolar transistor. Basic laboratory applications of the bipolar transistor. The emitter follower, the common emitter amplifier, and transistor biasing.
4. Nonlinear applications of transistors and transistor switches. Bipolar saturation and storage time. Comparison of small-signal and power transistors.
5. The junction field-effect transistor and its applications. The source follower and the common source amplifier. Input and output impedances of JFET circuits. Biasing and frequency response of JFET devices. Metal oxide semiconductor characteristics and the MOSFET.
6. FET families, polarities, and symbols. MOSFET devices and their laboratory applications. MOSFET devices as logic switches and power switches. Gate capacitances and switching speed.
7. Introduction to active filters and their transfer functions. Basic active filter configurations, using the op-amp. The Sallen-Key configuration and its variants. Poles, overshoot, damping and the special transfer characteristics of the Bessel, Butterworth, and Chebyshev types. Filter applications in the laboratory, such as a high-Q bandpass filter for optical detection.
8. Introduction op-amps as general-purpose analog building blocks. Inverting, non-inverting and summing amplifiers. Gain-bandwidth product and frequency response of op-amp circuits. Introduction to feedback principles.
9. Comparison of idealized and actual op-amp configurations. Finite input and output impedances, bias currents, offsets, and their treatment. The transimpedance amplifier and the photodiode as optical sensor. Also, ideal diodes, differentiators, and integrators implemented with op-amps.

D. LABORATORIES: As above.

E. COURSE COORDINATOR: P. Crooker

Revised: 10/01

Department Guide to Reason and Enlightenment

(DGRE)

PH4991 Relativity and Cosmology (4-0)

A. **CATALOG DESCRIPTION**: This course is a graduate level introduction to the current thought on the origin of space, time and matter. Topics covered are: The discovery of the cosmic evolution, Description of space in Newtonian and Einsteinian terminology, Kinematics and Dynamics of the Einstein cosmological models, the thermal history of the universe, the very early universe, the problems of a possible quantum origin of the universe and the possible future of the universe. Prerequisites: Courses in Basic Physics and Differential Equations.

B. **SUGGESTED TEXT**: *Gravity, An Introduction to Einstein's General Relativity*, J.B. Hartle, Addison Wesley, 2003

Part I – Space and Time in Newtonian Physics and Special Relativity
- Space, Time, and Gravity in Newtonian Physics
- Principles of Special Relativity
- Special Relativistic Mechanics

Part II – Curved Spacetime and General Relativity
- Gravity as Geometry
- Description of Curved Surfaces
- Tensor Analysis
- Energy-Momentum Tensor
- General Relativity
- Geometry Outside a Spherical Star
- Gravitational Lensing

Part III – Cosmology
- Astrophysical Survey
- Cosmological Models
- Big Bang Cosmology
- Inflation and the Accelerating Universe

C. **LABORATORY**: None

D. **COURSE COORDINATOR**: Jim Luscombe

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(DGRE)

PC2911, INTRODUCTION TO COMPUTATIONAL PHYSICS (3-2)

A. **COURSE DESCRIPTION**: An introduction to the role of computation in physics, with emphasis on the programming of current nonlinear physics problems. Assumes no prior programming experience. Includes a tutorial on the C programming language and Matlab as well as an introduction to numerical integration methods. Computer graphics are used to present the results of physics simulations.

B. **RECOMMENDED TEXT**: Giordano, *Computational Physics*, 1997

C. **COURSE CONTENTS**:

Topics	Approx. Hrs
1. Fundamentals of C programming.	3
2. Radioactive decay.	2
3. Projectile trajectories and air drag.	4
4. Planetary and satellite orbits.	4
5. Nonlinear damped and driven oscillations.	4
6. Wave propagation in various media.	4
7. Fourier transforms and spectral analysis.	2
8. Random number distributions.	2
9. Chaos in simple nonlinear systems.	2
10. Molecular dynamics (optional).	2

D. **LABORATORY**: Students will work at their own pace on programming assignments, either in a computer laboratory or at home.

E. **COURSE COORDINATOR**: J. Blau

Revised: 6/05

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(DGRE)

PC3014 INTERMEDIATE APPLIED PHYSICS LABORATORY (3-4)

A. CATALOG DESCRIPTION: This course continues with the instrumentation and signal processing topics begun in SE2013. Included are: controllable oscillators and RF modulation/demodulation techniques, basic electrical noise sources, device damage and failure modes, elementary digital logic gates and ICs. Also included are an overview of relevant microcomputer topics, such as digital encoding schemes, analog and digital interfacing, and serial communications and networking. At the discretion of the instructor, hands-on projects incorporating the course material, may be assigned. Typical projects are: in-air sonar systems, radio receivers and transmitters, and opto-electronic communications links. Prerequisites: SE2911 and SE2013, or permission of instructor.

B. RECOMMENDED TEXTS: none

D. COURSE SYLLABUS

1. Review of applications of Fourier series to periodic signals. The Fourier integral and Fourier transform, and their applications to the analysis of both periodic and non-periodic signals. Introduction to the Fourier signal analyzer as a laboratory instrument. The general Fourier transfer function of a system.
2. Introduction to oscillators. Monostable and astable devices. Review of LC resonance. Phase-shift, LC Hartley, LC Colpitts and crystal oscillators. Oscillators as signal sources. Voltage-controlled oscillators. Simple AM and FM modulation techniques and their uses.
3. Natural noise sources, Johnson noise, shot noise, 1/f noise, ground loop currents, EMI, and phase-sensitive detection.
4. Binary ASCII character codes, and related topics. Boolean algebra and logical gates and their hardware implementation. Introduction to CMOS digital logic families and their characteristics.
5. Use and application of NAND, NOR, inverting, AND, OR gates, and tri-state logic.
6. Monostables and clocks. Introduction to the fundamentals of digital memory and data storage.
7. A/D and D/A conversion and its applications in the laboratory. Digital sampling and the Nyquist sampling theorem. Sample-and-hold devices.
8. Introduction to digital signal analysis including sampling, FFT's, aliasing, windowing, leakage, spectral parameter estimation, and correlation.
9. The RS-232 serial interface and/or Universal Serial Bus (USB) and localized digital interfaces. Optional discussion of modem technology.
10. Overview of modern serial digital communication and networking technology. Packetized data streams and Ethernet, collision detection and re-transmission. Switched packet data streams and ATM, and Quality of Service (QoS). High performance network backbones, and fiber-optic digital communication techniques.
11. Introduction to embedded microprocessors.

D. LABORATORY: As Above

E. COURSE COORDINATOR: P. Crooker

Revised**:** 6/02

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PC3172 FLUID DYNAMICS OF WEAPONS, SHOCK WAVES, AND EXPLOSIONS (4-2)

A. CATALOG DESCRIPTION: This course provides the basic physics applicable to air-borne and water-borne missiles, as well as the fluid dynamics of shocks and explosions. Topics include: Elements of thermodynamics, ideal fluid flow, elementary viscous flows, similitude and scaling laws, laminar and turbulent boundary layers, underwater vehicles, classical airfoil theory, supersonic flow, drag and lift of supersonic airfoils with applications to missiles, fluid dynamics of combustion, underwater explosions. Prerequisites: PH2151 and PH3991.

B. RECOMMENDED TEXT: Instructor's notes

C. COURSE CONTENT:

Elements of thermodynamics : 5 hours
The First law of thermodynamics and the equation of state; Intensive and extensive quantities; Entropy and the second law of dynamics; Thermodynamics processes; Enthalpy

Ideal fluid flows 5 hours
The equation of continuity; Euler's equation; Bernoulli's equation; Incompressible fluids; Physical interpretation of vorticity

Elementary viscous flows 5 hours
The equation of motion of a viscous fluid and boundary conditions; Flow in a pipe; Plane parallel shear flow due to an impulsively moving boundary; Boundary layer flow

Dynamical similarity and scaling laws
5 hours

Laminar and turbulent boundary layer flows 8 hours
The laminar boundary layer; Flow near the line of separation; The turbulent boundary layer; Flow past a flat plane; Flow past streamline bodies; Zhukovskii theorem; Induced drag

Underwater vehicles 5 hours
Drag reduction; Torpedo design considerations; Dynamics of a straight-running torpedo

Supersonic flow 7 hours
Propagation of disturbances in a moving fluid; Steady flow of a fluid; Surfaces of discontinuity and the shock adiabatic; The formation of shock waves in supersonic flow past bodies; Subsonic and supersonic flows past a thin wing; The laws of transonic similarity and hypersonic similarity

Fluid dynamics of combustion 5 hours
Detonation; The propagation of a detonation wave; Scaling laws for explosions; Underwater explosions

D. LABORATORY: Videos

E. COURSE COORDINATOR: B. Borden

DGRE 3/03

PC3200 PHYSICS OF ELECTROMAGNETIC SENSORS AND PHOTONIC DEVICES (4-1)

A. COURSE DESCRIPTION An introductory survey of the physics of active and passive electromagnetic detection systems, primarily for Combat Systems students who do not elect to follow the Electromagnetic Sensors specialization track. Basic radiometry. Introduction to radar: ranging, pulse rate and range ambiguity, Doppler measurements, radar equation, target cross-sections, antenna beam patterns and phased arrays. Optoelectronic displays: CRTs, LEDs, LCDs, plasma displays. Introduction to lasers: transitions, population inversion, gain, resonators, longitudinal and transverse resonator modes, Q-switching, mode-locking, laser applications. Photodetection basics: noise and its characterization, photovoltaic, photoconductive and photoemissive detectors, image intensifiers, CCDs, night vision systems. Introduction to optical fibers and their applications. PREREQUISITES: PH2652, PH3292 and PH3352, or equivalent(s), or by permission of instructor.

B. RECOMMENDED TEXTS
1.} J. Wilson and J. Hawkes, {\it Optoelectronics - an Introduction, 3rd edition}, Prentice -- Hall Europe (1998), ISBN 0-13-103961-X.
2.} T. P. Pearsall, {\it Photonics Essentials, an Introduction with Experiments}, McGraw -- Hill (2003), ISBN 0-07-140875-43.
3.} S. O. Kasap, {\it Optoelectronics and Photonics Principles and Practices}, Prentice -- Hall (2001), ISBN 0-201-61087-6.

COURSE CONTENTS
1. Review of fundamental concepts of geometric and physical optics, atomic and molecular physics, and semiconductor physics, as appropriate.
2. Survey of optical fiber technology. Stepped-index and graded-index fibers, propagation modes, numerical aperture, losses, coherent fiber bundles.
3.} The basic physics of lasers: Review of spontaneous and stimulated emission, absorption, Einstein coefficients and Einstein relations. State populations, rate equations, and their solutions under conditions of local thermodynamic equilibrium.
4.} Pumping and population inversion. Steady-state solutions of rate equations with pumping. Gain, saturation, attenuation and threshold criterion. Homogeneous and inhomogeneous line broadening.
5.} Resonant cavities and their behavior. Modes of resonant cavities. Q-switching, mode locking and modulation techniques.
6.} Optoelectronic photodetection. PN junction and heterojunction devices.
7.} Photovoltaic, photoconductive, photoemissive and bolometric detectors. Noise and its characterization. Figures of merit.
8.} Imaging systems, detector arrays, CCD and focal plane imaging devices, FLIRs. Image intensifiers and night vision systems.
9.} Basic radiometry and the quantitative characterization of radiative energy transport.
10.} Introduction to optoelectronic displays: Cathode ray tubes, light-emitting diodes and LED displays, liquid crystal displays, plasma displays.
11.} Introduction to radar: Ranging, pulse rate and duration effects, range ambiguity, radar equation. Doppler techniques. Review of diffraction and its relationship to antenna beam patterns and phased arrays.

LABORATORY: Demonstrations

FACULTY CONTACT: D. S. Davis

DGRE 7/03

PC3400 SURVEY OF UNDERWATER ACOUSTICS (4-2)

CATALOG DESCRIPTION: The physics of generation, propagation, and detection of sound in the ocean. Topics include the acoustic wave equation and its limitations in fluids; plane, cylindrical, and spherical waves; the ray approximation; reflection of plane waves from plane boundaries; radiation of sound from circular piston, continuous line source, and linear array; speed of sound and absorption in the ocean; active and passive sonar equations; transmission-loss and detection-threshold models; normal mode propagation in the ocean; the parabolic equation approximation. Laboratory experiments include surface interference, noise analysis, normal modes, and acoustic waveguides. PREREQUISITES: PH2151 and PH3991.

SUGGESTED TEXT: Kinsler, Frey, Coppens, and Sanders, *Fundamentals of Acoustics, 4th Edition*.

COURSE CONTENT:	HOURS
1. The Wave Equation Development of the linear wave equation, effects of viscosity, relations between acoustic variables; plane, spherical, and cylindrical waves; ideal boundary conditions.	12
2. Surface Interference Image theory; Lloyd's mirror and its applications.	4
3. Reflection and Transmission Normal and oblique plane wave reflection and transmission at plane fluid-fluid boundaries.	8
4. The Shallow Water Channel	2
5. Sources and Receivers Source level, directivity, power output, radiation impedance; linear arrays; effects of spacing, shading, and phasing; piston radiators; estimation of radiation patterns; sensitivitiesof transmitters and receivers.	12
6. Ray Theory The derivation of the Eikonal and transport equations; the Eikonal equation and ray tracing; the transport equation and acoustic intensity.	3
7. Absorption of Sound in the Ocean	2

FACULTY POC: Prof. Steve Baker

Revised 3/00

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PC3800 SURVEY OF THE EFFECTS OF WEAPONS (4-0)

A. **CATALOG DESCRIPTION**: Physics of high-velocity impact including the dynamical behavior of ductile and brittle materials and shock waves in solids. Physics of projectile penetration at high velocities. Shaped charges. Nuclear weapons effects including blast and shock thermal radiation, X-rays, neutron flux, electromagnetic pulse, and radioactive fallout. Biological and chemical weapons effects, deployment, detection and countermeasures. Directed energy weapons and effects. PREREQUISITE: SE3172 and PH2652.

B. **RECOMMENDED TEXT**: Instructor's notes.

C. **COURSE CONTENT**

TOPICS	
1. Explosive Warhead Types, Effects and Countermeasures	10 hours
a. Air-Blast	
b. Underwater Bubble	
c. Metal Projection (fragmentation, shaped charge (incl., EFP, Hemi))	
2. Nuclear Weapons	10 hours
a. Design Principles	
b. Phenomenology of nuclear explosions	
c. Nuclear Weapons Effects	
3. Chemical/Biological Warfare & Countermeasures	9 hours
a. Physiological Mechanisms	
b. Micro/Macro Attack Methods	
c. Weapon Stability	
d. Meteorological Effects	
e. Detection Methods	
4. Directed Energy Weapons and Effects	15 hours
a. Candidate Lasers for Weapons Applications	
b. High-Powered Microwaves	
c. Target Interactions	

D. **LABORATORY**: None

E. **COURSE COORDINATOR**: B. Borden

DGRE 3/03

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PC4015 ADVANCED APPLIED PHYSICS LABORATORY (3-4)

A. CATALOG DESCRIPTION: Students must integrate the material that they learned in the previous two courses (SE2013 and SE3014), along with additional material on embedded microprocessors and controls. A working introduction to control systems theory is provided and incorporated into an autonomous weapon system or "robot." Collaborative and autonomous engagement of the robots will be performed with RF modems and Ethernet communications. The principles of cooperative engagement will be emphasized. For the final exam, teams will compete in 2-on- I or 2-on-2 engagement contests. These contests will test the students' assimilation of both the formal and the practical aspects of the course material. **Prerequisites:** SE2911 or other C/C++ programming course, plus SE2013 and SE3014. Pass/fail: Not applicable.

B. RECOMMENDED TEXT:

C. COURSE CONTENT

1. Introduction to microprocessors. Embedded processor hardware features, use, and programming system. Parallel interfacing, handshaking, polling, and interrupts.
2. The microprocessor, continued. Elements in C programming style and special topics including multitasking and real-time control issues. Robot-to-computer interfacing, motion commands, and interrupt based boundary detection.
3. Angular discrimination with a photodetector pair, and sensitivity analysis. Sensitive AC optical detection circuit including analog multiplexing, tuned filters, with synthesis of previous circuit application building blocks and op-amp knowledge.
4. A/D interfacing of the optical detection circuit to the microprocessor, settling time, bandwidth, and sensitivity adjustments; and rudimentary feedback tracking with the robot.
5. Feature and use of RF full-duplex modems providing communication between embedded robot processor and personal computer. Autonomous network communications between personal computers.
6. Feedback and control theory. PID controllers and their Bode analysis. Criteria for stability and discussion of gain margin and phase margin. The block diagram of the robot feedback system and analysis.
7. Demonstration of P (proportional) and improved PD (proportional-derivative) feedback tracking with the robot. Extra lab time.
8. Introduction to the standard robot weapon. Driving the firing solenoid with a MOSFET circuit, timing issues, and speed control options for the gun motors. Spurious noise and interference issues as they relate to the optical detection circuitry.
9. Review of robot competition rules and lab time. Precompetition (finding the bugs).
10. Extra lab time and final robot competition.

D. LABORATORY

E. COURSE COORDINATOR: R. Harkins

Revised:

PC4022 COMBAT SYSTEMS CAPABILITIES(3-0)

A. CATALOG DESCRIPTION: An advanced study of the technical capabilities of current acquisition programs within DoD. The course begins with an overview of the Navy acquisition community and the acquisition process. This is followed by weekly presentations by program managers and their technical experts. Overviews of each program are followed by an in-depth analysis of the critical physics and engineering issues, design trade-offs, risk areas, reliability issues, use of simulation and modeling, testing and evaluation rationale, interoperability concerns, software development issues, interfacing issues, etc. Topics of the course are dictated by the availability of program office personnel.

PREREQUISITES: SECRET US clearance.

B. RECOMMENDED TEXT: None

C. COURSE CONTENT: Varies depending on the availability of outside speakers and student interests. Every attempt is made to have a well-rounded set of topics covering the major combat systems such as radar, sonar, missiles, ship self-defense, etc.

D. LABORATORY: None

E. COURSE COORDINATOR: D. KAPOLKA

Revised: 07/03

PC4860 ADVANCED WEAPON CONCEPTS (4-1)

A. CATALOG DESCRIPTION: This course is a comprehensive overview of the components and underlying technologies of modem missile technologies. The course gives an introduction to missile guidance, missile aerodynamic design considerations, and missile propulsion technologies, followed by an introduction to the physics of modem conventional warhead designs for missile intercept and lethality and survivability considerations. PREREQUISITES: SE3172 and good comprehension of all aspects of mechanics and electromagnetics.

B. RECOMMENDED TEXT: Instructors notes.

C. COURSE CONTENT

1. Missile Aerodynamic Design considerations — 20 hours
   a. Irrotational flow of ideal gasses
   b. Lift and drag of thin airfoils
   c. Lift and drag of slender bodies of revolution in supersonic flow
2. Introduction to missile control — 15 hours
   a. Small perturbation analysis and the linearized equations of motion
   b. Feedback control systems
   c. The Laplace transform and root-locus stability analysis
3. Introduction to missile guidance — 10 hours
   a. Pursuit, constant-bearing, and proportional guidance schemes
   b. The Kalman filter
   c. Sources of noise in optical and radar guided missiles
   d. Command and beam-rider guidance
4. Missile propulsion — 5 hours
   a. Propulsion methods
   b. Rocket propulsion design considerations
   c. Design considerations
5. Warhead technologies — 1 hour
   a. Modern warhead design
   b. High velocity impact and penetration
   c. Lethality and survivability considerations
6. Fuzes — 4 hours
   a. Fuze types and methods
   b. Redundancy in Safing and Arming
   c. Problems and trends in future Target Detection Device development

D. COURSE COORDINATOR: B. Borden

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PH0820 Integrated Project (0-12)

A. CATALOG DESCRIPTION: The Naval Postgraduate School provides many opportunities for students to participate in campus-wide interdisciplinary projects. These projects encourage students to conceptualize systems which respond to current and future operational requirements. An integral part of the project involves working with other groups to understand and resolve issues involved with system integration. This course is available to Combat Systems Science and Technology students who are participating in a campus-wide integrated project. PREREQUISITES: Permission of instructor.

B. RECOMMENDED TEXT: None

C. COURSE CONTENT: Varies depending on the central problem chosen for the overarching project and student interest. Integrated project students enrolled in this course are expected to choose a topic involving some technical depth in applied physics.

D. LABORATORY: None

E. GRADING: Pass/ Fail

F. SECURITY CLEARANCE REQUIRED: None

Course Coordinator: D. Kapolka

Revised: FEB 04

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(DGRE)

PH1000 The Nature and Structure of Physics (4-2)

A. CATALOG DESCRIPTION The concepts and laws of physics are explored from the ancient science of Aristotle and Ptolemy through the beginnings of classical physics with Galileo and Newton through the modern quantum and relativity physics of Schrodinger and Einstein to the physics of quarks and neutrino oscillations. Physics concepts are explored and their relevance to every day and military technologies is highlighted. The course is designed for students who will not take a physics based curriculum, but will encounter technologies impacted by physical concepts. The goal in this course is to convey an appreciation for physics as an intellectual endeavor and an understanding of the principles underlying modern technology. Prerequisites: None.

B. RECOMMENDED TEXT: Sheldon Glashow, From Alchemy to Quarks, The Study of Physics as a Liberal Art, Brooks/Cole Publishing Company, 1993, ISBN 0-534-16656-3

C. COURSE CONTENT	HOURS
Introduction, Historical and Prehistorical	**3**
Motion, Energy and Momentum	6
Behavior of Gasses, Heat	7
Atoms (Chemistry)	4
Electricity and Magnetism	5
Waves (including optics and acoustics)	6
Atoms, Quantum Mechanics	8
Relativity	4
Nuclear Physics, Technologies	4
Elementary Particle Physics	4
Standard Model, Cosmology	4
Quizzes, field trips	11

D. **LABORATORIES**, Demonstrations and field trips

E. **COURSE COORDINATOR**: D. Kapolka

DGRE: 9/02

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PH 1001 FUNDAMENTALS OF PHYSICS I (4-2)

A. CATALOG DESCRIPTION: This course meets for twelve hours per week for the first five and one-half weeks of the quarter. Topics covered are the fundamentals of calculus-based mechanics: Kinematics and dynamics of particles, statics of rigid bodies, work, energy, systems of particles, collisions, rotations of rigid bodies, angular momentum and torque, mechanical properties of solids, elasticity, harmonic motion, sound, fluids. Mathematical methods are reviewed as required. PREREQUISITES: Calculus with a passing grade.

B. RECOMMENDED TEXT: Halliday, Resnick, Walker, Fundamentals of Physics, 6th edition

C. COURSE CONTENTS:

All topics to be covered in a 5 ½ week course of 44 lecture hrs.

1. Math review: vectors and derivatives--4 hr.
2. Kinematics of particle motion--3
3. Dynamics of particle motion--4
4. Work and energy--4
5. Momentum, systems of particles (including center of mass)--3
6 1- and 2-D collisions--3
7. Rotational motion, torque, angular momentum--4
8. Rotation and translation of rigid bodies--3
9. Harmonic motion--4
10. Waves (for space students) or Elastic modulus and fluids (for physics students) -- 4
12. Gravity--4

D. LABORATORY: Problem Sessions

E. COURSE COORDINATOR: D. Kapolka

DGRE: 10/02

PH 1002 FUNDAMENTALS OF PHYSICS II (4-2)

A. CATALOG DESCRIPTION: This course meets for twelve hours per week for the second six weeks of the quarter and covers basic electromagnetism: electric charge, electric and magnetic fields, forces on charges in fields, electric potential, Gauss's law, Ampere's law, Faraday's law, resistance, capacitance, inductance, DC circuits, magnetic properties of matter, transient currents in circuits, complex AC circuit analysis, Maxwell's equations. Mathematical methods are reviewed as required. Prerequisite: PH1001 or equivalent.

B. RECOMMENDED TEXT: Halliday, Resnick, Walker, Fundamentals of Physics, 6th edition

C. COURSE CONTENTS:

All topics to be covered in an 5 ½ week course of 44 lecture hrs
1. Electric charge, Coulomb's law--2
2. Electric field--3
3. Gauss's law--2
4. Electric potential--3
5. Capacitance, capacitors, dielectrics--3
6. Current, resistance, resistors--3
7. DC circuits--3
8. Magnetic field--1
9. Lorentz force, Hall effect, radius of gyration—3
10. Forces on current-carrying wires--2
11. Ampere's law--2
12. Faraday's law--2
13. Inductance and inductors—3
14. Complex Circuit Analysis--6
17. Maxwell's equations, differential and integral forms—2
18. E&M Oscillations -- 2
19. E&M Waves -- 3

D. LABORATORY: Problem Sessions

E. COURSE COORDINATOR: D. Kaploka

DGRE: 10/02

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PH 1121 MECHANICS (4-2)

A. CATALOG DESCRIPTION: This course covers the fundamentals of calculus-based mechanics: Kinematics and dynamics of particles, statics of rigid bodies, work, energy, systems of particles, collisions, rotations of rigid bodies, angular momentum and torque, mechanical properties of solids, elasticity, harmonic motion, fluids. Prerequisite: A course in calculus or concurrent registration in a calculus course and approval of the instructor.

B. RECOMMENDED TEXT: Halliday, Resnick, and Walker, Fundamentals of Physics, 6th edition.

C. COURSE CONTENT:

All topics to be covered in an eleven week course of 44 lecture hrs.

1. Measurements and vectors--2 hr.
2. Kinematics of particle motion--5
3. Dynamics of particle motion--4
4. Gravity--2
5. Simple Harmonic Motion--3
6. Work and Energy--4
7. Momentum, collisions, center of mass--8
8. Rotation, torque, angular momentum, equilibrium--8
10. Solids and fluids, elastic moduli—8

D. LABORATORIES:

Measurement and Error
Falling Bodies with Drag
Projectile Motion
Newton's Laws
Collisions in One and Two Dimensions
Angular Acceleration, Momentum, and Collisions

E. COURSE COORDINATOR: D. Kapolka

Revised 8/02

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(DGRE)
PH 1322 Electromagnetism (4-2)

A. CATALOG DESCRIPTION: This calculus-based course covers basic electromagnetism: electric charge, electric and magnetic fields, forces on charges in fields, electric potential, Gauss's law, Ampere's law, Faraday's law, resistance, capacitance, inductance, DC and AC circuits, magnetic properties of matter, transient currents in circuits, Maxwell's equations, electromagnetic waves. Prerequisite: PH 1121 or approval of the instructor.

B. RECOMMENDED TEXT: Halliday, Resnick, and Walker, Fundamentals of Physics, 6th edition.

C. COURSE CONTENT: All topics to be covered in an eleven week course of 44 lecture hrs.

1. Electric charges, forces, and field, Gauss's Law—6
2. Electric potential—4
3. Capacitors and dielectrics—6
4. DC circuit analysis—4
5. Magnetic field, Lorentz force—8
6. Electromagnetic Induction, Transients—6
7. AC Circuit analysis—6
8. Maxwell's equations, EM waves—4

D. LABORATORIES:
Electric Field Mapping
Charging and Discharging Capacitors
Thevenin Equivalents and Input and Output Resistance
Diode Characteristics and Applications
AC Filters

E. COURSE COORDINATOR: D. Kapolka

Revised: 11/02

PH1994/95 Special Topics in Elementary Physics (8-2)

A. CATALOG DESCRIPTION: This course provides a review of the basic Mathematics required for Physics. Topics include: Topics from single and multivariate Calculus that are applicable to a description of the physical world; vector algebra and vector Calculus; Complex numbers; Differential Equations; and a review of Linear Algebra. Prerequisites: Any undergraduate Mathematics sequence appropriate to Physics and Engineering majors.

B. RECOMMENDED TEXT: Mathematical Methods for Physics and Engineering, by Riley, Hobson, and Bence (Cambridge Univ. Press)

C. COURSE CONTENT:

(1) Algebraic Preliminaries	5 hours
(2) Basic Calculus	12 hours
(3) Series and Limits	13 hours
(4) Complex Numbers and Hyperbolic Functions	5 hours
(5) Partial Differentiation	12 hours
(6) Vector Algebra	5 hours
(7) Multiple Integrals	10 hours
(8) Vector Calculus	10 hours
(9) Line, Surface, and Volume Integrals	13 hours
(10) First-Order Differential Equations	10 hours
(11) Higher-Order Ordinary Differential Equations	10 hours
(12) Matrices and Vector Spaces	10 hours

D. COURSE COORDINATOR: B. Borden

DGRE 9/03

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PH 2001: RESEARCH SEMINAR IN PHYSICS (1-0)

A. CATALOG DESCRIPTION: This course will present the research expertise of the physics faculty. The course is designed to support Combat Systems Science and Technology students in their second quarter in the selection of their concentration and area for thesis research. The course is given in the Pass/Fail mode. PREREQUISITES: CSS&T students in their second quarter or consent of Academic Associate.

B. RECOMMENDED TEXT: None.

C. COURSE CONTENT:

1. Presentations by faculty having Master's thesis topics.
2. Presentation by Academic Associate of procedures for selection degree option, concentration, and thesis topic.

D. LABORATORIES: None

E. COURSE COORDINATOR: D. Kapolka

Revised: 6/2005

Department Guide to Reason and Enlightenment (DGRE)

PH2151 Analytical Mechanics I (4-1)

A. CATALOG DESCRIPTION: After a review of the fundamental concepts of kinematics and dynamics, this course concentrates on those two areas of dynamics of simple bodies which are most relevant to applications in Combat Systems: vibrations and projectile motion. Topics include: damped and driven oscillations, projectile motion with atmospheric friction, satellite orbits, and rotating coordinate systems. PREREQUISITES: PH1121 or equivalent; MA2121 or equivalent course in ordinary differential equations (may be taken concurrently).

B. RECOMMENDED TEXT: J. R. Taylor, *Classical Mechanics*.

C. COURSE CONTENTS:

Week	Chapter	Subject
1	2	Rectilinear motion of a particle
2	2	Rectilinear motion of a particle
3	3	Oscillations
4	3	Oscillations
5	4	Particle motion in three dimensions
6	4	Particle motion in three dimensions
7	5	Noninertial reference frames
8	5	Noninertial reference frames
9	6	Gravitation and central forces
10	6	Gravitation and central forces
11	6	Gravitation and central forces

D. LABORATORY: none

E. FACULTY CONTACT: Bruce Denardo

Revised Dec 02

Department Guide to Reason and Enlightenment

(DGRE)

PH2351 ELECTROMAGNETISM (4-1)

A. CATALOG DESCRIPTION: Electrostatic fields in vacuum and dielectrics, electrostatic energy and capacitors. The magnetic field of steady currents, Biot-Savart and Ampere's Laws, vector potential, magnetic properties of matter. Faraday's law. Magnetic energy. Maxwell's Equations. PREREQUISITES: PH1322 or equivalent, a course on multivariable calculus and a course in differential equations.

B. RECOMMENDED TEXT: Griffiths, Introduction to Electrodynamics, 3rd edition.

C. COURSE CONTENT

1. The electric field (2 hours)
   Gauss' Law (2 hours)
   Electric potential (2 hours)
   Work and energy (2 hours)
   Conductors & capacitors (2 hours)
2. Laplace's equation (2 hours)
   Method of images (2 hours)
   Separation of variables (3 hours)
   Multiple expansion (2 hours)
3. Polarization (2 hours)
   Electric displacement (2 hours)
   Linear dielectrics (2 hours)
4. Lorentz force law (2 hours)
   Biot-Savart law (2 hours)
   Magnetic vector potential (2 hours)
5. Magnetization (2 hours)
   Auxiliary field H (2 hours)
   Linear and nonlinear media (2 hours)
6. Electromagnetic force (2 hours)
   Electromagnetic induction (2 hours)
   Maxwell's equations (3 hours)

D. LABORATORY: Problem sessions

E. COURSE COODINATOR: R. Armstead

Revised: 3/00.

PH 2401 INTRODUCTION TO THE SONAR EQUATIONS (3-0)

A. **CATALOG DESCRIPTION**: A discussion of each term of the sonar equation, with application to the detection, localization, and classification of underwater vehicles. Topics include ray acoustics, simple transmission loss models, tonals, spectrum and band levels, directivity index, array gain, doppler shift, and detection threshold. This course can also be taken on-line as part of the ASW Certificate. PREREQUISITES: Precalculus mathematics.

B. **RECOMMENDED TEXT**: Coppens, Sanders, and Dahl, Introduction to the Sonar Equations.

C. **COURSE CONTENT**:
   3. Fundamentals of sound propagation in the ocean
   4. Transmission loss models
   5. Combining signals
   6. The sonar equations

D. **LABORATORIES**: None

E. **COURSE COORDINATOR**: D. Kapolka

Revised: 6/2005

PH2514 INTRODUCTION TO THE SPACE ENVIRONMENT (4-0)

A. **COURSE DESCRIPTION:** Plasma concepts. Solar structure and magnetic field, particle and electromagnetic emissions from the sun, the geomagnetic field, and the magnetosphere, radiation belts, structure and properties of the earth's upper atmosphere, ionosphere, implications of environmental factors for spacecraft design. PREREQUISITE: A course in basic electricity and magnetism.

B. RECOMMENDED TEXT: None

C. COURSE CONTENTS:

Topics	Approx. Hrs
1. Modern Physics	3
2. Plasma Physics	4
3. Solar Physics	8
4. Solar Wind	4
5. Geomagnetism	3
6. Earth's Magnetosphere	8
7. Earth's Atmosphere	3
8. Earth's Ionosphere	3
9. Spacecraft-Environment Interactions – Spacecraft Charging	3
10. Spacecraft-Environment Interactions – debris and atmospheric effects	1
11. Spacecraft-Environment Interactions – Radiation Effects	4

D. LABORATORY: None

E. FACULTY CONTACT: R. C. Olsen

Revised 6/02

Department Guide to Reason and Enlightenment

(DGRE)

PH2652 MODERN PHYSICS (4-1)

A. COURSE DESCPRIPTION: An introduction to modern physics. Theory of relativity; blackbody radiation; photoelectric effect; matter waves; atomic spectral lines; Bohr model of the atom; uncertainty relations (position-momentum and time-energy); the Schrödinger equation (time dependent and independent); probability interpretation; infinite, finite and parabolic potential wells; tunneling (single and double barriers); electron spin and exclusion principle; the periodic table; molecular energy levels; quantum statistics (Bose-Einstein, Fermi-Dirac). PREREQUISITE: PH1121 and PH1322

B. RECOMMENDED TEXT: Stephen T. Thornton and Andrew Rex, *Modern Physics for Scientists and Engineers* (2nd ed., 2000, Harcourt Brace, NY)

C. COURSE CONTENT:

1. Theory and applications of special relativity	6
2. Blackbody radiation; photoelectric effect; Rutherford scattering	4
3. Atomic structure and spectral lines; Bohr model	4
4. De Broglie waves, wave packets, uncertainty relations	2
5. Schrödinger equation and probability interpretation	4
6. Infinite, finite and parabolic potential wells	8
7. Tunneling (single and double barriers)	4
8. Spin and exclusion principle; periodic table	4
9. Quantum statistics (Bose-Einstein, Fermi-Dirac)	6
10. Superconductivity	2

D. LABORATORY: Selected demonstration experiments and problem sessions

E. COURSE COORDINATOR: G. Karunasiri

Revised 8/03

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(DGRE)

PH2724 Thermodynamics (4-0)

A. COURSE DESCPRIPTION: Equations of state; the concepts of temperature, heat and work; the first law of thermodynamics; heat engines and refrigerators; entropy and the second law of thermodynamics; thermodynamic potentials; phase equilibrium; kinetic theory; equipartition theorem; transport phenomena. Prerequisites: PH1121, PH1322, MA1116.

B. RECOMMENDED TEXT: Schroeder, An Introduction to Thermal Physics (Addison-Wesley, 2000)

C. COURSE CONTENT:

1. Energy in thermal physics (2 weeks): thermal equilibrium, ideal gas, equipartition of energy, heat and work, compression work, heat capacity, kinetic theory

2. Second law (3 weeks): two-state systems, Einstein model of a solid, interacting systems, large systems, ideal gas, entropy

3. Interactions and implications (2 weeks): temperature, entropy and heat, paramagnetism, mechanical equilibrium and pressure, diffusive equilibrium and chemical potential

4. Engines and refrigerators (2 weeks): heat engines, refrigerators, real heat engines, real refrigerators

5. Free energy (2 weeks): available work, force toward equilibrium, phase transformations, dilute solutions

D. LABORATORY: None

E. COURSE COORDINATOR: B. Denardo

Revised 2/09

PH 3002 NON-ACOUSTIC SENSOR SYSTEMS FOR USW (4-0)

A. CATALOG DESCRIPTION: This course covers the physical principles underlying the operation of a number of operational and proposed non-acoustic sensor systems. Geomagnetism magnetometers and gradiometers, MAD signatures, optical and IR transmission in the atmosphere and in seawater, Image converter, FLIR and radar system for USW, and exotic detection schemes.

PREREQUISITES: PH1322

B. TEXTBOOK: Instructor's notes.

C. COURSE CONTENT:

1. Radar System Applications to USW.

2. Noise Sources.

3. Laser Radar (LIDAR).

4. Radiation Detection Devices.

5. Submarine Thermal Wake Physics.

6. Bioluminescence and its Potentials.

7. Magnetic Detection-of Submarines and Mines

8. Hydrodynamic Effects and their Detection.

D. LABORATORY: None

E. COURSE COORDINATOR: A. Larraza

Revises: 8/02

Department Guide to Reason and Enlightenment

(DGRE)

PH3052 PHYSICS OF SPACE & AIRBORNE SENSOR SYSTEMS (4-0)

A. **COURSE DESCRIPTION**: This inter-disciplinary course explores the physical principles underlying the sensor systems needed for satellites and tactical aircraft as well as limitations imposed by the atmosphere and operating environment on these systems and their communication links. Topics include: satellite orbits, the satellite environment, ionospheric interactions and atmospheric propagation, phased array and pulsed compressed radars, imaging synthetic aperture and inverse synthetic aperture radars, noise resources, thermal radiation, principles of semiconductor devices, optical and infrared imaging detector systems and their resolution limitations and bandwidth requirements. PREREQUISITE: Basic physics course. Must be familiar with the concepts of energy and wave motion.

B. **RECOMMENDED TEXT**: R.C. Olsen, *Remote Sensing from Air and Space*

C. **COURSE CONTENTS**:

Topics	Approx. Hrs
1. Order of Battle, Types of Imagery	4
2. Basics of Electromagnetic waves, quantum mechanics	4
3. Visible Imaging, basic optics, Detectors, Atmospheric Transmission, Rayleigh Criteria	4
4. Visible Imaging systems: Corona, Hubble, IKONOS, DMSP	4
5. Orbital Mechanics	4
6. Spectral imagery, Landsat, SPOT, AVIRIS	4
7. Image Processing	2
8. IR Imaging, thermal sensors, GOES	4
9. Radar basics – range and azimuth resolution, SAR concepts	4
10. Shuttle Imaging Radar, civil SAR satellites, Lynx UAV	4
11. Radar: Coherent Change Detection, topo mapping; Milli-meter wave	4

D. **LABORATORY**: None

E. **COURSE COORDINATOR**: R.C. Olsen

Revised: 6/02

Department Guide to Reason and Enlightenment

(DGRE)

PH 3119 OSCILLATIONS AND WAVES (4-2)

A. COURSE DESCRIPTION: An introductory course designed to present mechanics to students studying acoustics. Kinematics, dynamics, and work energy considerations for the free, damped, and driven oscillators. The wave equation for transverse waves in bars. Transverse waves on rectangular and circular membranes. Vibration of plates. Laboratory periods include problem sessions and experiments on introduction to experimental techniques and handling of data; the simple harmonic oscillator analog; transverse waves on a string; and transverse, longitudinal, and torsional waves on a bar. PREREQUISITES: PH3991 or equivalent.

B. RECOMMENDED TEXT: Kinsler, Frey, Coppens and Sanders, *Fundamentals of Acoustics, 4th Edition*.

C. COURSE CONTENTS:

Topics	Approx. Hrs
1. The Harmonic Oscillator	12
Review of complex notation and the simple harmonic oscillator. The damped, forced harmonic oscillator (resonance, mechanical impedance, and energy). Equivalent circuit analogues	
2. Transverse Waves on Strings	10
The one-dimensional wave equation. General properties of waves (waveform and wave speed). The driven, semi-infinite string (transmitted power). The drive-fixed and driven-mass-loaded string (resonance and input impedance). Free vibrations of a fixed-fixed string (normal modes). Approximate, graphical, and numerical solution to transcendental equations. Reflection and transmission at the junction of two strings	
3.Waves in Bars	12
Waves in homogeneous, isotropic solids. Definition of various elastic moduli, Poisson's ratio, and their interrelation. Longitudinal and torsional waves in bars. Transverse waves on bars and dispersion.	
4. Waves on Rectangular and Circular Membranes	10

D. LABORATORY: Experimental Techniques
Handling Data
Simple Harmonic Oscillation Analog
Transverse Waves on a String
Transverse, Longitudinal, and Torsional Waves on a Bar

E. FACULTY CONTACT: Steve Baker

Revised 6/03

Department Guide to Reason and Enlightenment

(DGRE)

PH3152 ANALYTICAL MECHANICS II (4-0)

A. CATALOG DESCRIPTION: Dynamics of systems of particles, including rockets. Hamilton's principle, Lagrangian dynamics, and the role of physical symmetry. Velocity-dependent potentials. The inertia tensor and the rotational dynamics of rigid bodies. Small-amplitude oscillations of systems of particles, and normal modes. PREREQUISITE: PH2151

B. RECOMMENDED TEXT: J. R. Taylor, *Classical Mechanics*.

C. COURSE CONTENTS:

week	chapter
1	7. Dynamics of systems of particles
2	7. (continued)
3	8. Rigid body motion in a plane
4	8. (continued)
5	9. Rigid body motion in three dimensions
6	9. (continued)
7	9. (continued)
8	10. Lagrangian mechanics
9	10. (continued)
10	11. Oscillating systems
11	11. (continued)

D. LABORATORY: none

E. COURSE COORDINATOR: B. Denardo

Revised: 1/02

Department Guide to Reason and Enlightenment

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PH 3204 PRINCIPLES OF ELECTRO-OPTIC SENSOR SYSTEMS (4-2)

A. **CATALOG DESCRIPTION**: The first course of a two-course sequence for Interdisciplinary Curricula. This course treats the principles and capabilities of military electro-optic and infrared systems in a Range Equation context. Topics include: target signatures and backgrounds, optical transmitter and receiver characteristics, MTF and OTF, atmospheric propagation and propagation codes, laser radiation and types, fiber optics, detectors, focal plane arrays, D* and NET, principles of imaging, and sensor performance parameters. Laboratory work provides hands-on familiarity with modern infrared devices. Prerequisites: PH1322, MA3139 or equivalent.

B. **RECOMMENDED TEXT** “ The Electro-Optic and Infra-Red Systems Handbook “ SPIE/ERIM1993. Intro. To InfraRed and Electro-Optic Systems; Driggers, Cox and Edwards, Artech

C. **COURSE CONTENT**:

	Topics	Approx. Hours
1	The Electro-optical Environment; EO Terminology, Electro-Optical Spectrum; Transmission Bands; Quantization - The Photon; Night Vision and Thermal IR. EO Range Equation. Wave velocity and Refractive index,	3
2	Refraction, reflection and imaging, the camera and telescopes. Measures of Performance; Effective Aperture, F/#, Numerical Aperture. Stops, Effective Aperture.	3
3	Thermal and Quantum Radiation sources; Planck radiation, emissivity and reflectivity, Atomic and Molecular Transitions.	4
4	Imaging and Diffraction; Resolution. Point Spread Function, Spatial period and Spatial Frequencies, Transfer Functions.	3
5	Sources ; Photons, Energy States and Transitions.; Line and Continuous Spectra, Thermal radiation, Planck Function, Emissivity and Reflectivity; Specific emitters, sources. Beer's Law and Transmittance, Optical signatures of air and land vehicles.	3
6	Transition Line Widths, Stimulated Emission, Resonators. Basics of Laser action. Laser categories and output characteristics.	4
7	Total Internal Reflection , guided waves, in fibers, basics of fiber optics. Material attenuation, dispersion , pulse length and guided wave modes; mode dispersion, pulse spreading . Optical and modulation bandwidth, data rate. LED and Diode Lasers for Fiber optics.	7
8	Atmospheric Propagation of optical radiation; refraction, absorption, scattering; Propagation Models, LOWTRAN/MODTRAN. Turbulence. Optical Receivers, Resolution, MTF and OTF.	4
9	Detectors and Scanners; Principles of Imaging; Pixels. Thermal and Semiconductor (PE, PC and PV) detectors. Noise, Performance Parameters; Responsivity, D* and NET. Focal Plane Arrays, CCDs	4
10	Scanning and Staring Imaging Systems; FLIR, IRST, IRLS. Performance Parameters, MRT and Range Prediction.	4
	Examinations, Reviews, Holidays	5

Total Class Hours 44

D. **LABORATORY**: Selected from:

1. Helium Neon Laser Fundamentals.
2. Lenses and Telescopes
3. TV Contrast Transfer Function.
4. Pockels Effect.
5. Staring (PtSi) Thermal Imaging.
6. Fourier Plane Processing
7. He/Ne Laser Spectrum
8. LOWTRAN Atmospheric Code Computation.

E. COURSE COORDINATOR: A.W. Cooper

Revised 2/09

EC/PH3280 and ME 3780:
Micro Electro Mechanical Systems (MEMS) Design I (3-3).

To Be Offered Winter Quarter (Q2)

I. Catalog Description

This is a 4.5 credit hour class introducing the students to Micro Electro Mechanical Systems (MEMS). Topics include material considerations for MEMS and microfabrication fundamentals. Surface, bulk and non-silicon micromachining. Forces and transduction; forces in micro-nano-domains and actuation techniques. Case studies of MEMS based microsensor, microactuator and microfluidic devices. The laboratory work includes computer aided design (CAD) of MEMS devices and small group design project. Prerequisites: basic understanding of electrical and mechanical structures: EC2200 or MS2201 or PH1322 or consent of instructor..

II. Text and References

A. Recommended Texts:

Microsystem Design, Stephen D. Senturia, Kluwer Academic Publishers; Boston (2001). ISBN-0-7923-7246-8.

B. Alternative Texts: None.

III. Expected Outcomes

The student should develop an understanding of design, modeling, and fabrication techniques for MEMS devices and application of this technology to military systems.

IV. Required Background Experience

1. Understanding of solid mechanics and material science.
2. Understanding of semiconductor device fundamentals.

V. Detailed Description of the Course

A. Expanded Description of the Course

Introduction to MEMS	
Materials for MEMS	1 hrs
MEMS structures and devices	2 hrs
Microfabrication Fundamentals	
Review of IC fabrication technologies	3 hrs
Bulk micromachining	3 hrs
Surface micromachining	3 hrs
Process integration	3 hrs
Forces and Transduction	
Forces in micro and nano domains	3 hrs
Static mechanics: mechanical properties, beam bending	3 hrs
Dynamics and vibrations	3 hrs
Resonant sensing	3 hrs
Electrostatic actuation and capacitive position sensing	3 hrs
Piezoelectric transduction	3 hrs
Total	33 hrs

B. Method of Instruction and Evaluation

A lecture and self study modes of instruction is used and is complemented with laboratory exercises. A design project proposal is required on developing a MEMS device. The actual design project will be performed in the subsequent course MEMS Design II. Students are graded on homework from text, Midterm and final exams, and the design proposal paper.

VI. Computer Usage

The use of MEMSPro CAD for MEMS software, ANSYS Multi-Physics Finite Element Analysis software, and SPICE Circuits Simulator are utilized to design and model MEMS components and systems.

VII. Laboratory

Laboratory exercises consist of design, simulation, and analysis of MEMS devices using MEMSPro and ANSYS software.

1.	Fundamentals of MEMSPro	3 hrs
2.	Design of MEMS electrical and mechanical components	5 hrs
3.	Introduction to ANSYS-FEM simulation software	3 hrs
4.	Simulation of MEMS components and devices (systems)	5 hrs
5.	MEMS design optimization	3 hrs
6.	Design Project Presentations	3 hrs
	Total	22 hrs

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%)   Design: 1 credit hrs (25%)

B. Design Content

Homework, examinations, and computer usage involve design of MEMS devices in software.

C. Design Attribute

Development of student creativity:

Students perform creative designs of MEMS devices and circuits.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for:

Curriculum 533:

COMBAT SYSTEMS ANALYSIS, SIMULATION AND TESTING: Sufficient foundation in Systems Analysis and Simulation to understand the limits of each, and their effect on required combat systems testing.

COMBAT SYSTEMS ENGINEERING: An understanding of the principles of design, development, upgrades and maintenance; and the importance of performance and economic trade-offs in combat systems.

MATERIALS SCIENCE: A familiarity of the concepts of materials science sufficient for an understanding of the mechanical, electrical, and thermal properties of materials important in present and future combat systems.

Curriculum 570:

MATERIALS AND FABRICATION: Metallurgical processes and transformations; analytical approach to failure of materials in Naval Engineering use and a basic understanding of the materials technology associated with welding and marine corrosion; an introduction to the developing fields of composites and superconducting materials.

DESIGN/SYNTHESIS: Design synthesis and introduction to optimization techniques, with emphasis on the design of mechanical subsystems and their integration into the ship system.

ELECTRICAL ENGINEERING: Electromagnetic and circuit theories, dc circuits, steady-state ac circuits, methods of circuit analysis, including Laplace transforms. Exposure to the construction and operating characteristics of rotating machinery, static converters, and power distribution systems and multiphased circuits.

Curriculum 590:

ELECTRONIC AND ELECTRICAL ENGINEERING: In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter-counter measures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

SYSTEM DESIGN AND SYNTHESIS: The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system related operational requirements and criteria

CONDUCTING AND REPORTING INDEPENDENT INVESTIGATION: The officer will demonstrate the ability to conduct an independent investigation on a Navy and/or DOD relevant electronic systems problem, to resolve the problem, and present the results of the analysis in both written and oral form.

Curriculum 591:

SPACECRAFT STRUCTURES, MATERIALS AND DYNAMICS: An understanding of the engineering of space structures including simplified sizing calculation and analytical modeling of advanced materials which can be incorporated in system design and integration.

An ability to apply reliability and maintainability to testing, evaluation, and manufacturing which can be used to predict the functional dependability of spacecraft structures.

CONDUCT AND REPORT INDEPENDENT RESEARCH: The ability to conduct independent research on a space systems problem, to resolve the problem, and to present the results of the analysis in both written and oral form.

X. Course Coordinators

Prof. Gamani Karunasiri
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Prof. Jose O. Sinibaldi
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Prof. Todd R. Weatherford
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PH3292 APPLIED OPTICS (4-2)

A. CATALOG DESCRIPTION: An intermediate-level course in optics. Review of basic geometric and physical optics concepts. Laws of reflection and refraction at interfaces. Imaging systemsand aberrations. Polarization; Jones matrix methods; electro-optical modulation. Matrix methods for paraxial ray tracing and optical systems analysis. Two-beam and multiple-beam interference; Young's double slit experiment, multiple-slit systems and diffraction gratings; Michelson's interferometer; Fabry-Perot interferometer. Huygens-Fresnel principle; Fraunhofer diffraction; Fresnel diffraction. PREREQUISITES: PH1623 and PH3352, or equivalents.

B. TEXT: E. Hecht, *Optics, 3rd ed*., Addison Wesley Longman (1998), F. L. Pedrotti and L. S. Pedrotti, *Introduction to Optics, 2nd ed*., Prentice Hall (1993), and M. V. Klein and T. E. Furtak, *Optics, 2nd ed*., John Wiley and Sons (1986).

C. COURSE CONTENTS:

Review of basic geometric optics: Rays, waves, index of refraction, reflection, refraction at plane and spherical surfaces, lenses, spherical mirrors, imaging systems, linear and angular magnification.
Matrix methods of ray tracing: ABCD ray matrix representations of plane and spherical surfaces, system matrix analysis of multiple-component optical systems and instruments.
Brief introduction to aberrations. Linear polarizers, dichroism, birefringence, quarter-wave and half-wave retarders, circular and elliptical polarization, Jones matrices.
Optical activity, Pockels effect, Kerr effect. Review of basic interference phenomena: electromagnetic wave equation, superposition. Plane and spherical waves, Young's double slit apparatus.
Multiple-beam interference, Fabry-Perot etalon. Huygens-Fresnel principle. Multiple-slit interference,
Fraunhofer diffaction by single slits, rectangular apertures and circular apertures.
Multiple-slit diffraction, diffraction gratings. Beam patterns and angular resolution of optical systems. Introduction to Fresnel diffraction.
Fresnel diffraction by apertures and obstacles. Fresnel intergrals. Babinet's principal.

D. LABORATORY: Experiments and/or demonstrations at the discretion of the instructor.

E: COURSE COORDINATOR: D. S. Davis

Revised: 8/02

Department Guide to Reason and Enlightenment

(DGRE)

PH3352 ELECTROMAGNETIC WAVES (4-0)

A. **COURSE DESCRIPTION**: Maxwell's equations, energy density and Poynting vector, boundary conditions. Polarization. Propagation of uniform plane waves in vacuum, dielectrics, conducting media (with emphasis on sea water) and low-density neutral plasmas. Reflection and refraction at plane dielectric and conducting boundaries, at normal and oblique incidence. Rectangular waveguides. PREREQUISITES: PH2351

B. **RECOMMENDED TEXT**: Griffiths, Introduction to Electrodynamics, 3rd Ed.

C. **COURSE CONTENTS:**

	Topics	Approx. Hrs
1.	Displacement Current, Maxwell's Equations, Electromagnetic Energy and Poynting's Theorem, Wave Equation, Boundary Conditions on Time-Dependent Fields, Wave Equation with Sources, Gauge Transformation	12
2.	Uniform Plane Harmonic Waves in Nonconducting and Conducting Media, Polarization, Wave Impedance, Complex Propagation constant, Dispersion, Group Velocity	12
3.	Uniform Plane Harmonic Waves in Low-Density Neutral Plasma, Introduction to Ionospheric Radio Wave Propagation	3
4.	Reflection and Refraction at the Plane Interface between two Dielectric Media at Normal and Oblique Incidence, Snell's Law, Fresnel Reflection and Transmission Coefficients in terms of both Refraction Indices and Impedances, Critical Angle and Brewster Angle	6
5.	Reflection and Refraction at the Plane Interface between Dielectric and conductor at Normal Incidence, Complex Fresnel Coefficients, Quantitative treatment of Oblique Incidence	3
6.	Propagation between Two Parallel Conduction Plates, Rectangular Waveguides, TE Modes	6

D. **LABORATORY**: none

E. **COURSE COORDINATOR**: R. Armstead

Revised: 7/02

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PH3360 Electromagnetic Wave Propagation (4-1)

A. **CATALOG DESCRIPTION**: Introduction to vector fields and the physical basis of Maxwell's equations. Wave propagation in a vacuum, in dielectrics and conductors, and in the ionosphere. Relection and refraction at the interface between media. Guided waves. Radiation from a dipole. PREREQUISITES; MA2121 and a course in basic electricity and magnetism.

B. **RECOMMENDED TEXT**: Elements of Electromagnetics by Matthew Sadiku (3rd Edition) by Oxford University Press

C. COURSE CONTENT:

Topic	Hours
Review of Vector Calculus and Coordinates	4
Electrostatic Fields	4
Electric Fields in Material Space	5
Magnetostatic Fields	3
Magnetic Forces	3
Maxwell's Equations	4
Electromagnetic Wave Propagation	5
Transmission Lines	2
Waveguides	5
Antennas	5
Wave Propagation in the Ionosphere	2
Radar Equation	2

D. LABORATORY: Problem Sessions

E. COURSE COORDINATOR: R. Armstead

Revised: 02/9

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PH 3401 INTRODUCTION TO THE SONAR EQUATIONS (3-0)

A. CATALOG DESCRIPTION: A discussion of the fundamental principles behind each term of the sonar equations. Starting with the acoustic wave equation and the basic properties of sound waves, topics include ray acoustics, normal mode theory, simple transmission loss models, coherent and incoherent sound, directivity, beamforming, scattering, noise sources and properties, and the detection threshold. This course can be taken on-line as part of the ASW Certificate program. Prerequisites: Single-variable calculus

B. RECOMMENDED TEXT: Introduction to the Sonar Equations by Coppens, Sanders, Dahl, and Kapolka. Provided on-line via Blackboard.

C. COURSE CONTENT:

7. Fundamentals of Sound
8. Transmission Loss Models
9. Ray Theory
10. Surface Interference
11. Normal Modes
12. Sources and Receivers
13. Detecting Signals in Noise
14. Signal Processing
15. Passive Sonar Equations
16. Active Sonar Equations
17. Side Scan Sonar

D. LABORATORIES: None

E. COURSE COORDINATOR: D. Kapolka

Revised: 3/2009

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PH3451 FUNDAMENTAL ACOUSTICS (4-2)

A. CATALOG DESCRIPTION: Development of, and solutions to, the acoustic wave equation in fluids; propagation of plane, cylindrical, and spherical waves in fluids; sound pressure level, intensity, and specific acoustic impedance; normal and oblique incidence reflection and transmission from plane boundaries; transmission through a layer; image theory and surface interference; sound absorption and dispersion for classical and relaxing fluids; acoustic behavior of sources and arrays, acoustic reciprocity, continuous line source, plane circular piston, radiation impedance, and the steered line array; transducer properties, sensitivity, and calibration. Laboratory experiments include longitudinal waves in an air-filled tube, , properties of underwater transducers, modes in a cylindrical cavity, speed of sound in water, and absorption in gases. PREREQUISITES: PH3119 and PH3991 or equivalent.

B. SUGGESTED TEXT: Kinsler, Frey, Coppens, and Sanders, *Fundamentals of Acoustics, 4th Edition*.

C. COURSE CONTENT: HOURS

1. Waves in Fluids — 12

Fundamentals of fluid mechanics (equations of continuity, state, and motion). The small-amplitude three-dimensional wave equation. The thermodynamic speed of sound; isothermal vs. adiabatic propagation. Plane and spherical waves. Acoustic variables (pressure, condensation, Particle velocity, wave speed, and densoty). Specific acoustic impedance. Energy density, intensity, and SPL.

2. Sources of Sound — 16

Simple source (point and finite radius). Continuos line source. Piston source (near and far field), radiation impedance, and power radiated. Beam patterns, directivity index, and source level. Line arrays. Product theorem. Transmitting and receiving sensitivities.

3. Transmission Phenomena at Boundaries Between Fluids — 8

Transmission and reflection at normal and oblique incidence. Normal incidence, reflection, and transmission at layers. Image theory and surface interference.

4. Absorption — 8

Complex propagation constant. Absorption and dispersion for classical and relaxing fluids. Discussion of chemical relaxation effects and absorption coefficients for seawater. Thermal and viscous layers at boundaries.

D. LABORATORY

Longitudinal Waves in a Tube
Helmholtz Resonances
Modes in a Recangular Cavity
Modes in a Cylindrical Cavity

E. COURSE COORDINATOR: B. Denardo

Revised 4/00

Department Guide to Reason and Enlightenment

(DGRE)

PH3452 UNDERWATER ACOUSTICS (4-2)

A. CATALOG DESCRIPTION: This course is a continuation of PH3451. It covers an introduction to the sonar equations, simple transducers, and beamforming; the steady state response of acoustic waveguides of constant cross-section, propagating and evanescent modes, and group and phase speeds; transmission of sound in the ocean, the Eikonal Equation and necessary space conditions for ray theory, and refraction and ray diagrams; sound propagation in the mixed layer, the convergence zone, and the deep sound channel; ambient noise; Doppler effect and bandwidth considerations; target strength and reverberation; and topics in basic signal processing and detection. Laboratory experiments include the three element array, surface interference, water-filled waveguide, and noise analysis. PREREQUISITES: PH3451.

B. SUGGESTED TEXT: Kinsler, Frey, Coppens, and Sanders, Fundamentals of Acoustics, 4^{th} Edition and instructor course notes, Underwater Acoustics for Naval Applications.

C. COURSE CONTENT:

Topics	Approx. Hrs.
1. Sonar Equations	4
2. Sources and Receivers	8
3. Sound Propagation	4
4. Sound in the Ocean	4
5. Waveguides	4
6. Noise	4
7. Target Strength and Reverberation	4
8. Signal Processing and Detection	8
9. Sonar System Design	4

D. LABORATORY:
1. The Three element Array
2. Surface Interference
3. Water-Filled Waveguide
4. Noise Analysis

E. COURSE COORDINATOR: D. Kapolka

Revised: 2/09

Department Guide to Reason and Enlightenment

(DGRE)

PH3655 SEMICONDUCTOR DEVICE PHYSICS (4-0)

A. **COURSE DESCRIPTION**: Formation of solids, crystal structure of semiconductors, X-ray diffraction, lattice vibrations, defects, electrical and thermal properties, free electron model, Seebeck effect, thermionic emission, photoemission, effects of periodic potential, formation of energy bands, E-k relation, band structure of Si and GaAs, electrons and holes, doping and impurity levels, mobility, diffusion, continuity equation, Schottky and ohmic contacts, optical properties, Formation of p-n junction, I-V characteristics, bipolar and field effect transistors, fabrication technology, semiconductor alloys, quantum effect devices, fundamental limits to semiconductor device technology.
PREREQUISITES: PH2652.

B. **RECOMMENDED TEXT**: S. O. Kasap, Principles of Electronics Materials and Devices (2^{nd} Edition)

C. **COURSE CONTENT**:

1.	Crystal structure, diffraction and defects		8
2.	Electrical and thermal properties		4
3.	Free electron model and applications		6
4.	Formation of energy bands and E-k relation	6	
5.	Optical properties of semiconductors		4
6.	Formation of Schottky and p-n junctions		4
7.	Bipolar and field effect transistors	2	
8.	Semiconductor alloys and quantum effect devices	4	
9.	Fundamental limits to semiconductor device technology		2

D. **LABORATORY**: none

E. **COURSE COORDINATOR:** G. Karunasiri

Revised: 8/03

Department Guide to Reason and Enlightenment

(DGRE)

PH3782 THERMODYNAMICS and STATISTICAL PHYSICS (4-0)

A. COURSE DESCRIPTION: Entropy, temperature, Boltzmann factor and Gibbs factor are developed from a quantum point of view. Blackbody radiation, chemical potential, partition function, Gibbs sum and applications to an ideal gas are covered. Fermi-Dirac and Bose-Einstein statistics and applications to degenerate systems; Gibbs free energy, Helmholtz free energy, enthalpy, kinetic theory, phase transformations, chemical reactions. Prerequisites: PH2724 and PH2652.

B. **RECOMMENDED TEXT**: *An Introduction to Thermodynamics and Statistical Mechanics*, K. Stowe, Cambridge University Press, 2007

C. **COURSE CONTENT**:

1. Elements of Probability Theory
2. Energy and the First Law of Thermodynamics
3. Interactions Between Systems (heat, work, particle transfer)
4. Accessible States, Entropy, and the Second Law of Thermodynamics
5. Thermodynamic potentials, Third Law of Thermodynamics
6. Boltzmann distribution
7. Information Theory
8. Kinetic Theory and Transport Processes in Gases
9. Magnetic Properties
10. Partition Function
11. Quantum Statistics
12. Degenerate Fermi Gas
13. Blackbody radiation
14. Thermal properties of solids
15. Degenerate Bose Systems

D. **LABORATORY**: none

E, **COURSE COORDINATOR:** J. Luscombe

Revised: 2/09

Department Guide to Reason and Enlightenment
(DGRE)

PH3858 Railgun Technology (2-0)

A. **CATALOG DESCRIPTION:** This course provides a basic introduction to the the fundamentals of railgun theory, design and practice. Requirements for both the Army and Navy applications are discussed. Acceleration of projectiles, pulsed power sources for the railgun, barrel life, mechanical stress, projectile design, and thermal considerations will be discussed. Prerequisite: PH1121 and PH1322 or approval of the instructor.

B. **RECOMMENDED TEXT:** Instructor notes.

C. **COURSE CONTENT:** All topics to be covered in an eleven week course of 22 lecture hrs.

a.	Railgun theory	8 hrs
b.	Materials considerations	2 hrs
c.	Range	1 hr
d.	Launcher practices	2 hrs
e.	Power conditioning	4 hrs
f.	Projectile design	2 hrs
g.	Thermal release	1 hr
h.	Innovations	2 hrs

D. LABORATORIES:
   a. None

E. **COURSE COORDINATOR:** Brett Borden

Revised: 4/6/05

PH3991 THEORETICAL PHYSICS (4-1)

A. **COURSE DESCRIPTION**: Discussion of heat flow, electromagnetic waves, elastic waves, and quantum-mechanical waves; applications of orthogonal functions to electromagnetic multipoles, angular momentum in quantum mechanics, and to normal modes on acoustic and electromagnetic systems. Applications of complex analysis to Green Function in quantum mechanics and electromagnetism. Application of Fourier series and transforms to resonant systems. Applications of partial differential equation techniques to equation of physics. PREREQUISITES: Basic Physics, multivariable calculus, vector analysis, Fourier series, complex numbers, and ordinary differential equations.

B. **RECOMMENDED TEXT**: Boas. Mathematical Methods in Physical Science, 2nd edition

C. **COURSE CONTENTS**:

Topics
1. Complex numbers and Physical applications
2. Vector analysis, gradient, line integrals, divergence, Strokes theorems
3. Vector analysis continued
4. Fourier Series
5. Series differential equation solutions, Legendre, orthogonality
6. Frobenius method, Bessel functions
7. to be announced
8. Partial differential equation of physics, temperature, vibrations, quantum
9. Complex functions
10. Complex functions continued
11. Fourier transforms
12. Final Exam, Monday

D. **LABORATORY**: Problem Sessions

E. **COURSE COORDINATOR**: R. Armstead

Revised: 7/02

Department Guide to Reason and Enlightenment

(DGRE)

PH4055 Free Electron Laser Physics (3-0)

A. CATALOG DESCRIPTION: The physical principles describing free electron lasers are explained with applications to ship defense from sea-skimming missiles, and to new radiation sources for scientific research. Theory is applied to experimental facilities around the world. Topics include optical resonator design, general laser concepts, laser beam propagation, relativistic electron dynamics, phase-space analysis, and numerical simulation. Prerequisite: PH4353

B. RECOMMENDED TEXTBOOK: None

C. COURSE CONTENT:
1. The history and attributes of free electron lasers are reviewed.
2. Spontaneous emission in the free electron laser and synchrotron sources.
3. Electron phase-space dynamics in the free electron lasers.
4. Small-signal, low-current free electron laser oscillators.
5. Mode competition and coherence development
6 Collective high-current, high-gain free electron laser amplifiers.
7. Strong optical fields, high-power instabilities, and saturation.
8. Gain degradation due to electron beam quality.
9. Short optical pulse evolution in oscillators.
10. The high-power tapered undulator.

D. LABORATORY: None.

E. COURSE COORDINATOR: W. B. Colson

DGRE: 02/9

Department Guide to Reason and Enlightenment

(DGRE)

PH4153 ADVANCED CLASSICAL MECHANICS 1 (4 - 1)

A. CATALOG DESCRIPTION: The first course in a two-course sequence covering classical mechanics at the advanced graduate level. Newtonian mechanics of single-particle and two-body central force systems, including orbital motion and scattering . Constraints, Lagrangian dynamics and generalized coordinates. Euler's formulation of rigid body mechanics. Small oscillations and systems of coupled oscillators.

1. **Prerequisites:** PH3152 and PH3991 or equivalents.
2. **Security classification:** None.

B. RECOMMENDED TEXT BOOKS:

1. *Classical Mechanics*, *third edition* by H. Goldstein, C. Poole and J. Safko, Addison Wesley (2002), ISBN 0-201-65702-3.

2. *Classical Dynamics, A Contemporary Approach* by J. V. Jose and E. J. Saletan, Cambridge University Press (1998), ISBN 0-521-63176-9.

C. COURSE CONTENT:

1. Review of Newtonian mechanics and conservation laws for point particles and systems of particles. Constraints, virtual work, d'Alembert's principle. Review of generalized coordinates and forces.

2. Langrangian dynamics for systems with static and velocity-dependent potentials.

3. The calculus of variations. Hamilton's principle and its relationship to Langrangian dynamics. Canonical coordinates and the basic conservation laws from the Langrangian perspective.

4. The two-body central force problem from the Newtonian and Lagrangian perspectives. Orbits and their classification.

5. The virial theorem and Bertrand's theorem. Kepler's problem.

6. The Laplace-Runge-Lenz vector and its conservation. Scattering in central force systems. Center-of-mass and laboratory coordinate systems. Rutherford scattering.

7. Kinematics of rigid body motion. Coordinate transformations, Euler angles, Cayley-Klein parameters.

8. Euler's theorem, commutation rules for finite and infintesimal rotations in three dimensions. Coriolis effect. Inertia tensor and principal axes for rigid bodies.

9. Euler's equations of motion. Torque-free systems. Symmetric tops. Precessional motion.

10. General theory of small oscillations. Coupled oscilllators and transformation to normal coordinates.

11. Systems of driven and damped coupled oscillators.

D. LABORATORY:

E. COURSE COORDINATOR:

PH4154 ADVANCED CLASSICAL MECHANICS 2 (4 - 1)

A. CATALOG DESCRIPTION: The second course in a two-course sequence covering classical mechanics at the advanced graduate level. Kinematics and dynamics of relativistic systems from the Lagrangian perspective. Hamilton's equations of motion and conservation laws. Poisson brackets and commutation. Hamilton-Jacobi formulation of mechanics and action-angle variables. Introduction to nonlinear dynamics and chaotic systems. Introduction to classical perturbation theory.

Prerequisites: PH4153 or equivalent.
Security classification: None.

B. RECOMMENDED TEXTBOOKS

1. *Classical Mechanics*, *third edition* by H. Goldstein, C. Poole and J. Safko, Addison Wesley (2002), ISBN 0-201-65702-3.

2. *Classical Dynamics, A Contemporary Approach* by J. V. Jose and E. J. Saletan, Cambridge University Press (1998), ISBN 0-521-63176-9.

C. COURSE CONTENT

1. Review of the postulates of the special theory of relativity. Lorentz transformations, velocity addition, Thomas precession.

2. 4-vectors and 1-forms, metric tensor.

3. Newtonian dynamics extended to relativistic systems. Relativistic kinematics of collisions and many-body systems. Energy, momentum and angular momentum in relativistic systems.

4. Lagrangian formulation of relativistic mechanics.

5. Hamiltonian dynamics and Hamilton's equations of motion. Cyclic coordinates and conservation theorems. The principle of least action.

6. Configuration and phase space concepts. Canonical transformations.

7. Poisson's formulation of mechanics. Poisson brackets and commutation, Lagrange brackets. Equations of motion in the Poisson formalism.

8. Hamilton's principal function and the Hamilton-Jacobi formulation of mechanics. Conservation laws and the Hamilton-Jacobi formalism.

9. Action-angle variables and phase space analysis of classical mechanical problems.

10. Introduction to chaotic systems. Poincare maps, attractors, Liapunov exponents.

11. Introduction to time-dependent and time-independent canonical perturbation theory.

D. LABORATORY:

E. COURSE COORDINATOR:

Department Guide to Reason and Enlightenment

(DGRE)
PH 4171 PHYSICS OF EXPLOSIVES (4-0)

A. CATALOG DESCRIPTION: The goals of the course are to provide in-depth and advanced understanding of explosives from theoretical and practical standpoints, to formulate the bases for evaluating competitive and alternative explosive systems, and to provide criteria for crisis management. This course covers advanced topics in explosive physics and chemistry: Molecular energetics of the explosive molecule including molecular orbital and valence bonding and resonance stabilization concepts and practical implications of sensitivity and energy potential, oxygen balance and thermodynamic, reaction rate theory, hot-spot theory, shock physics and detonation theory. Special topics in explosive technology and application as applied to metal driving, mine detection and neutralization, chemical and biological dissemination, and computational modeling are offered per student's interests. Prerequisite: SE3172 and PH2652

B. RECOMMENDED TEXTS:

- (Provided Text) Engineering Design Handbook, "Principles of Explosive Behavior", AMCP 706-180, US Army Materiel Command publication.
- (Reference Text) Paul Cooper, "Explosive Engineering", Wiley-VCH (1996),
- Selected Technical Publications

C. COURSE CONTENT:

Topics	Approx. Hrs
Types of Explosives	2
Nature of he Explosive Molecule	4
Explosive Compositions	2
Thermochemistry	4
Thermal Decomposition of Explosives & Hot Spot Theory	4
Shock Physics (Hugoniot, Shock Interactions)	4
Detonation Theory	4
Initiation & Growth of Detonation	4
Measurement of Detonation Characteristics	2
Sensitivity Testing & IM Requirements	4
Survey & Assessment of Military Explosives	4
Special Topics	6

D. LABORATORY: None

E. COURSE COORDINATOR: B. Borden

DGRE 3/03

Department Guide to Reason and Enlightenment

(DGRE)

PH4209 EO/IR SYSTEMS AND COUNTERMEASURES (3-2)

A. CATALOG DESCRIPTION: This unclassified course for students in interdisciplinary curricula treats the military applications and countermeasures to electro-optic systems, including IR and EO seekers and trackers, surveillance and missile and laser warning systems, and laser rangers and designators. Scanning FLIR and IRST systems and Staring array applications will be included. Signature suppression and generic active and passive countermeasure approached will be discussed including decoys and active IRCM. Laboratory work will deal with EO/IR devices and possible countermeasure techniques.

PREREQUISITES: PH3204, MA3139, or equivalent.

B. **RECOMMENDED TEXT**: The Infrared and Electro-Optical Systems Handbook; Vol 7, "Countermeasures", Pollock (ERIM/SPIE Press). Also Instructor's Notes.

C. **COURSE CONTENTS**:

	Topics	Hours
1.	Optical Tracking and guidance systems; reticles, TV correlation, track modes.	3
2.	Intercept Systems – Electro-Optical, FLIR, IRST.	3
3.	Signature Reduction ; Active and Passive Decoys; Seduction and Distraction. Ship Self-Protection.	3
4	Countermeasures to Reticle and Imaging Trackers; Flares and Jammers. Active IRCM.	3
5	IR Flare technology and Countermeasures.	3
6.	Countermeasure Review, Missile Warning Systems (MAWS) and Directional IRCM	4
7.	Laser Designators, Illuminators, and Rangers; Laser Warning Receivers.	3
8.	High Energy Lasers and propagation. Target Damage. Directed Energy countermeasures (DIRCM)	4
7.	Miscellaneous Counter-Counter Measures	2
8.	Multifunction Pods and Mounts	2
9	Examinations and Holidays	3
	Total Class Hours	33

D. **LABORATORY**: TBD from
1) TV Target Tracking
2) Resolution of Night Vision System
3) CO_2 Laser Output Spectrum
4) MRT of Thermal Imager
5) Pockells Cell Modulator
6) Acousto-Optic (Bragg) Spectrum Analyser
7) Interferometer measurement of laser output (HeNe)

E. **COURSE COORDINATOR**: A. Cooper

Revised 2/09

PH4271 LASERS, OPTOELECTRONICS AND ELECTRO-OPTICS I (4-1)

A. CATALOG DESCRIPTION: The first course in a comprehensive two-course sequence covering the physics of lasers, optoelectronic and electro-optical devices. Review of Atomic and molecular energy levels, time-dependent perturbation theory, radiative transitions, transition rates. Einstein A and B coefficients for spontaneous and stimulated radiative transitions, blackbody radiation. Optical attenuation and amplification, rate equations. Basic laser theory, gain saturation, homogeneous and inhomogeneous effects. Optical resonators, laser modes, coherence. Q-switching, mode locking, pulse compression, laser pumping and tuning mechanisms. Gaussian beams. Introduction to multiple-mode and single mode optical fibers. PREREQUISITES: PH3292, PH3352 and PH3655, or equivalent(s).

B. RECOMMENDED TEXT/REFERENCE

1. J. T. Verdeyen, *Laser Electronics, 3rd edition*, Prentice-Hall (1995), ISBN 0-13-706666-X.
2. A. Yariv, *Optical Electronics in Modern Communications, 5th edition*, Oxford University Press (1997), ISBN 0-19-510626-1.
3. W. T. Silfvast, *Laser Fundamentals*, Cambridge University Press (1996), ISBN 0-521-55617-1.
4. A. E. Siegman, *Lasers*, University Science Books (1986), ISBN 0-935702-11-3.
5. E. Rosencher and B. Vinter, *Optoelectronics*, Cambridge University Press (2002), ISBN 0-521-77813-1.

C. COURSE CONTENT

1. Review of electromagnetic theory, electromagnetic wave equation, basic geometric and physical optics, coherence concepts.
2. Matrix methods in geometric optics. Matrix ray-tracing analysis of optical beams; stable and unstable systems.
3. Paraxial wave equation and its applications to optical beams. Guided modes. Gauss-Hermite modes in cylindrical cavities and beams. ABCD matrix analysis of the properties of Gaussian beams.
4. Guided beams in optical fibers. Step-index fibers, numerical aperture, acceptance angle. Guided modes in step-index fibers. Graded-index fibers and Gaussian beams. Losses and dispersion in optical fibers.
5. Optical cavities and resonators. Modes, resonance, finesse, Q.
6. Review of thermodynamic equilibrium and thermal blackbody radiation. Review of atomic and molecular energy level structure. Stationary state quantum numbers, angular momentum. Review of time-dependent perturbation theory as applied to radiative transitions. Selection rules, transition probabilities, rates, Einstein A and B coefficients for spontaneous and stimulated transitions.
7. Line shapes, homogeneous and inhomogeneous broadening mechanisms.
8. Loss and gain in optical media. Population inversion and pumping.
9. Rate equations for multiple-level laser media. Gain threshold and saturation. Q-switching and mode-locking.
10. Specific lasers, such as ruby, HeNe, argon-ion, CO2, neodymium glass, erbium-doped fibers, *etc*.

D. LABORATORY: Problem sessions and demonstrations

E. FACULTY CONTACT: D.S. Davis

DGRE 10/03

PH4272 OPTOELECTRONICS AND ELECTRO-OPTICS II (4-1)

A. COURSE DESCRIPTION: The second course in a two-course covering the physics of lasers, optoelectronic and electro-optical devices. Physics of optoelectronic detection, noise, detector figures-of-merit. Photovoltaic, photoconductive, bolometric and charge-coupled (CCD) detector families. 1-D and 2-D (focal-pave array) detectors. Image intensifiers and night vision systems. Gaussian beams. Physics of optical fibers and their practical applications. Optical properties of anisotropic media and their applications, electro-optical effects and modulators. Introduction to nonlinear optics, optical harmonic generation, parametric amplification ad optical heterodyning. PREREQUISITES: PH3292, PH3352 and PH3655, or equivalent(s).

B. RECOMMENDED TEXT:

1. C.C. Davis, *Lasers and Electro-optics – Fundamental and Engineering*, Cambridge University Press (1996) ISBN 0-521-48403-0

C. COURSE CONTENTS:

Topics	Approx. Hrs
1. Introduction to the physics of optoelectronic detection: basic radiometry and radiometric units, power detectors, noise and its sources, responsvity, quantum efficiency, frequency response	
2.Photoconductive, photovoltaic, photoemissive and bolometric detector families. Introduction to noise characterization and detector figures-of-merit.	
3. Basic physics of charge-coupled devices (CCDs) and focal-plane array detectors, and their characteristics. Image intensifiers and night vision systems.	
4. Gaussian beams and their propagation characteristics.	
5. Optical fibers and Waveguides. Step-index and graded-index fibers. Guided modes in optical fibers. Mode dispersion and cutoff characteristics. Single and multiple-mode fibers. Erbium-doped fibers and amplification.	
6. Optical fiber applications: communications systems, opto-mechanical and opto-acousitcal transducers, Sagnac interferometer and optical fiber gyroscopes.	
7. Optical properties of, and wave propagation in, anisotropic media. Bifrefingence. Review of Jones matrix analysis of polarization-sensitve optical systems.	
8. Longitudinal and transverse electro-optical effects. Electro-optical modulators. Acousto-optical modulators.	
9. Introduction to nonlinear optics. Harmonic generation, parametric amplification, optical heterodyning.	

D. LABORATORY: problem sessions and demonstrations

E. FACULTY CONTACT: D. S. Davis

Revised 4/00

Department Guide to Reason and Enlightenment
(DGRE)
PH4273 PHYSICS OF ADVANCED IMAGING SYSTEMS (4-2)

A. **CATALOG DESCRIPTION**: A course in the physical optics of advanced imaging techniques. Introduction to Fourier optics, spatial frequency, sampling, and transfer function concepts. Beam diffraction from the linear systems/Fourier transform perspective: beam patterns, phased arrays, beam forming and beam steering. Wavefront coherence and its characterization. Optical transfer functions, modulation transfer functions and diffractionlimited resolution of optical and RF systems. Performance characterization of imaging systems: NEP, NEFD, MDFD, and MDTD. Introduction to optical information processing: spatial light modulators, optical correlation and pattern recognition, optical tracking. Introduction to atmospheric turbulence and its effects on beam propagation. Introduction to adaptive optics. PREREQUISITES: PH3292 or equivalent. PH4272 is recommended as a concurrent course.

B. **RECOMMENDED TEXT**:

1 . J.W. Goodman, *Introduction to Fourier Optics,* 2nd *edition,* McGraw-Hill (1996), ISBN 0-07024254-2.
2. R.N. Bracewell, *Two-dimensional Imaging,* Prentice Hall (1995), ISBN 0-13-062621 -X.
3. J.W. Hardy, Adaptive Optics for Astronomical *Telescopes,* Oxford University Press (1998), ISBN 0-195-09019-5.
4. C. Scott, *Introduction to* Optics and Optical *Imaging,* IEEE Press (1988), ISBN 0-7803-3440-X.
5. R.K. Tyson, *Principles of* Adaptive Optics, Academic Press (1991), ISBN 0-12-705900-8.

C. **COURSE CONTENT**

1 . Review of 1-D Fourier transforms, Dirac delta functions and sampling. Introduction to 2-D Fourier transforms and associated concepts.
2. Angular spectrum (beam pattern), spatial frequency and 2-D sampling. Review of Huygens-Fresnel principle and its relevance to diffraction.
3. Rayleigh-Sommerfeld diffraction theory. Fraunhofer diffraction and beam forming from the 2D Fourier transform perspective. Beam patterns from rectangular, circular and more complex apertures.
4. Lenses and RF antennas as 2-D Fourier transform devices. Aperture arrays and phased arrays from the 2-D linear systems / Fourier transform perspective. Phase shifting, beam forming and beam steering.
5. Wavefront coherence and its characterization. Conditions for interference and fringe visibility. Spatial filtering.
6. Optical transfer function and modulation transfer function. Diffraction-limited performance of imaging and tracking systems.
7. Review of noise sources and noise characterization in detection processes. Performance figures-of-merit for imaging systems: system signal-to-noise ratio (SNR), noise-equivalent power (NEP), noise-equivalent flux density (NEFD), minimum-detectable flux difference (MDFD) and minimum-detectable temperature difference (MDTD).
8. Introduction to optical information processing. Correlation and pattern-recognition systems. Correlation tracking. Spatial light modulators and information processing by optical / photonic means.
9. Optical turbulence in the atmosphere and its statistical characterization: Komolgorov spectrum of turbulence, inner and outer scales, structure functions, isoplanatic wavefront patches and Fried's ro parameter, Greenwood frequency, Strehl ratio.
10. Introduction to adaptive optics. Shack-Hartmann wavefront sensors, deformable mirrors, artificial guide stars. Adaptive optics systems for modem military and astronomical applications.

D. **LABORATORY**: Experiments in Fourier optics and imaging systems

E. **COURSE COORDINATOR**: D.S. Davis

PH4274 PHYSICS OF ACTIVE ELECTROMAGNETIC DETECTION AND ENGAGEMENT (4-1)

A. **CATALOG DESCRIPTION**: A course in the physics of radar and high-power RF/microwave systems. Radiometry and the propagation of electromagnetic energy. Radar equation and its relationship to radiometry. Noise and minimum detection threshold criteria. Range gating, scanning and range ambiguity. Target cross-section and polarization effects. Doppler techniques. Correlation analysis of signals and signal coherence. Synthetic aperture methods. Absorption and scattering of RF/microwave beams by the atmosphere. Modulation and demodulation techniques, pulse compression, chirping and signal recovery. Ultra-wideband and monopulse radars. Tracking and jamming. Propagation of high-power beams and thermal blooming/defocusing in the atmosphere. Introduction to RF/microwave weapons and their effects. PREREQUISITES: PH2351 and PH3292.

B. **RECOMMENDED TEXT**:

1. W.L. Wolfe, *Introduction to Radiometry* SPIE Press (1998), ISBN 0-8194-2758-6.
2. B.E. Edde, *Radar Principles, Technology, Applications,* Prentice Hall (1993), ISBN 0-13752346-7.
3. W.L. Wolfe, Introduction to Radiometry, SPIE Press (1998), ISBN 0-8194-2758-6.
4. M.L. Skolnik, *Introduction to Radar Systems, 2nd edition,* McGraw-Hill (1980), ISBN 0-07-057909-1.
5. D.R. Wehner, *High-resolution Radar, 2nd edition,* Artech (1995), ISBN 0-890-06727-9.
6. G.W. Stimson, *Introduction to Airborne Radar,* IEEE Press (1998), ISBN 0-780-33491-4.

C. **COURSE CONTENT**

I . Radiometry and the transfer of radiative electromagnetic energy between sources and targets. Diffractive and geometric effects on radiative transfer. The fundamental radar equation and its relationship to radiometry. Noise characteristics and SNR thresholds for target detection.
2. Range gating techniques, scanning, range ambiguity.
3. Target characteristics and their effects on radar systems: target composition, orientation, shape, and geometry. Effective target cross-sections. Radiometric and polarimetric characterization of targets.
4. Review of I -D and 2-D Fourier transform concepts, autocorrelations, cross-correlations. Doppler techniques in radar. Correlation analysis of radar signals and signal coherence.
5. Modulation and demodulation techniques, pulse compression, chirping, more sophisticated modulation schemes. Tracking and jamming.
6. Review of beam patterns, beam forming and beam steering by phased-aperture and phased array techniques.
7. Synthetic aperture and inverse synthetic aperture methods.
8. Absorption and scattering of RF/microwave beams in the atmosphere. Effects of absorption and scattering on maximum range of target detection.
9. Ultra-wideband and monopulse radar systems.
10. Production of very high power RF and microwave electromagnetic radiation and their propagation through the atmosphere. Thermal blooming and defocusing. Introduction to RF/microwave weapons and their effects.

D. **LABORATORY**: Problem sessions and demonstrations

E. **COURSE COORDINATOR**: D. S. Davis

DGRE: 4/00

EC/PH4280 and ME4780:
Micro Electro Mechanical Systems (MEMS) Design II (2-4).

To Be Offered Spring Quarter (Q3)

I. Catalog Description

This is the second course in Micro Electro Mechanical Systems (MEMS) Design. This course will expose students to advanced topics on material considerations for MEMS, microfabrication techniques, forces in the micro- and nano-domains, and circuits and systems issues. Case studies of MEMS based microsensors, microactuators and microfluidic devices will be discussed. The laboratory work includes computer aided design (CAD) and characterization of existing MEMS devices. The grades will be based on exams, lab projects, and a group design project. Prerequisites EC/PH3280 or ME3780 or consent of instructor.

II. Text and References

A. Recommended Texts:

Microsystem Design, Stephen D. Senturia, Kluwer Academic Publishers; Boston (2001). ISBN-0-7923-7246-8.

B. Alternative Texts: None.

III. Expected Outcomes

The student should develop an understanding of design, modeling, fabrication, and fundamental characterization techniques for MEMS devices and application of this technology to military systems.

IV. Required Background Experience

3. Understanding of solid mechanics and material science.
4. Understanding of semiconductor device fundamentals.
5. Understanding of microfabrication techniques.

V. Detailed Description of the Course

A. Expanded Description of the Course

Microfabrication Techniques

Metals, Polymers, and Ceramics for MEMS	2 hrs
LIGA	1 hrs
Advanced Fabrication Techniques (Imprinting, Injection)	1 hrs

Circuits and Systems Issues

Electronics	2 hrs
Feedback	2 hrs
Noise	2 hrs

MEMS Design and Case Studies

Microaccelerometers	2 hrs
Microgyroscopes	2 hrs
Microsensors	2 hrs
Microheat exchanges	2 hrs

Microfluidics	2 hrs
Micro electronics and MEMS Process integration	2 hrs
Total	22 hrs

B. Method of Instruction and Evaluation

A lecture and self study modes of instruction are used and are complemented with laboratory exercises. A design project is required on developing a MEMS device to submit for fabrication to external MEMS fabrication facilities. Students are graded on homework from software tutorials, quizzes, and a design project.

VI. Computer Usage

MEMSPro CAD for MEMS software, ANSYS Multi-Physics Finite Element Analysis software, and SPICE Circuits Simulator are utilized to design and model MEMS components and systems. LabView will be used to perform data acquisition, MEMS driver control, and instrument control for MEMS device characterization.

VII. Laboratory

Laboratory exercises consist of design, simulation, characterization, and analysis of MEMS devices using MEMSPro, ANSYS, Inventor 3D, MATLAB, PSPICE and LabView software.

7. Fundamentals of MEMSPro	4 hrs
8. Design of MEMS electrical and mechanical components	6 hrs
9. Introduction to ANSYS-FEM simulation software	4 hrs
10. Simulation of MEMS components and devices (systems)	6 hrs
11. MEMS design optimization	4 hrs
12. Design for reliability	4 hrs
13. Characterization of Existing MEMS Devices	12 hrs
14. Design Project Presentations	4 hrs
Total	44 hrs

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%) Design: 2 credit hrs (50%)

B. Design Content

Homework, examinations, and computer usage involve design of MEMS devices in software.

C. Design Attribute

Development of student creativity:

Students perform creative designs of MEMS devices and circuits.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for:

Curriculum 533:

COMBAT SYSTEMS ANALYSIS, SIMULATION AND TESTING: Sufficient foundation in Systems Analysis and Simulation to understand the limits of each, and their effect on required combat systems testing.

COMBAT SYSTEMS ENGINEERING: An understanding of the principles of design, development, upgrades and maintenance; and the importance of performance and economic trade-offs in combat systems.

MATERIALS SCIENCE: A familiarity of the concepts of materials science sufficient for an understanding of the mechanical, electrical, and thermal properties of materials important in present and future combat systems.

Curriculum 570:

MATERIALS AND FABRICATION: Metallurgical processes and transformations; analytical approach to failure of materials in Naval Engineering use and a basic understanding of the materials technology associated with welding and marine corrosion; an introduction to the developing fields of composites and superconducting materials.

DESIGN/SYNTHESIS: Design synthesis and introduction to optimization techniques, with emphasis on the design of mechanical subsystems and their integration into the ship system.

ELECTRICAL ENGINEERING: Electromagnetic and circuit theories, dc circuits, steady-state ac circuits, methods of circuit analysis, including Laplace transforms. Exposure to the construction and operating characteristics of rotating machinery, static converters, and power distribution systems and multiphased circuits.

Curriculum 590:

ELECTRONIC AND ELECTRICAL ENGINEERING: In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter-counter measures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

SYSTEM DESIGN AND SYNTHESIS: The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system related operational requirements and criteria

CONDUCTING AND REPORTING INDEPENDENT INVESTIGATION: The officer will demonstrate the ability to conduct an independent investigation on a Navy and/or DOD relevant electronic systems problem, to resolve the problem, and present the results of the analysis in both written and oral form.

Curriculum 591:

SPACECRAFT STRUCTURES, MATERIALS AND DYNAMICS: An understanding of the engineering of space structures including simplified sizing calculation and analytical modeling of advanced materials which can be incorporated in system design and integration.

An ability to apply reliability and maintainability to testing, evaluation, and manufacturing which can be used to predict the functional dependability of spacecraft structures.

CONDUCT AND REPORT INDEPENDENT RESEARCH: The ability to conduct independent research on a space systems problem, to resolve the problem, and to present the results of the analysis in both written and oral form.

X. Course Coordinators:

Prof. Gamani Karunasiri
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Department Guide to Reason and Enlightenment

(DGRE)

PH4353 TOPICS IN ADVANCED ELECTRICITY AND MAGNETISM (4-0)

A. CATALOGUE DESCRIPTION: Topics selected from: Electromagnetic radiation, including radiation from antennas and accelerating particles, and radiation scattering from charged particles. Additional topics may include Cerenkov radiation, free electron lasers, and the relativistic formulation of electrodynamics. Prerequisites: PH3152, PH3352 and PH3991.

B. TEXT BOOK: Panofsky and Phillips, "Classical Electricity and Magnetism," Second Edition, (Dover)

C. COURSE CONTENT

- I. Maxwell's Equations
  - a. Conservation of charge
  - b. Gauss's Law
  - c. Ampere's Law
  - d. Faraday's Law of Induction
  - e. Faraday's Law in Moving Media
  - f. The Ampere-Maxwell Law
  - g. Maxwell's Equations in Media
    - i. Polarized Media
    - ii. Magnetic Media
    - iii. Constitutive Relations
    - iv. Ohm's Law
- II. Conservation Laws
  - a. Conservation of Energy
  - b. Conservation of Momentum
  - c. Induction
- III. Electromagnetic Waves
  - a. The Wave Equation
  - b. Plane Waves
  - c. The Reduced Wave Equation
  - d. Energy and Momentum
  - e. Reflection and Refraction at a Dielectric Interface
    - i. Boundary Conditions
    - ii. The Fresnel Relations
  - f. Propagation in Conductors
  - g. Group Velocity
- IV. Conducting Boundaries
  - a. Perfect Conductor Boundary Condition
  - b. Waveguides
    - i. TE Eigenvalues
    - ii. TE Fields
  - c. Cavities
  - d. Scattering by a Sphere
    - i. The Debye Potential Approach
    - ii. Generic Behavior
- V. Radiation and Scattering
  - a. The Vector and Scalar Potentials
  - b. The Retarded Potentials
  - c. Radiation Fields
  - d. Directivity
  - e. Radiation From Wires

i. Short Center-Fed Linear Antenna
ii. Half-Wave Dipole
f. Radiation From Apertures
i. Open-Ended and Slotted Waveguides and Horns
ii. Reflector Antennas
g. Phased Arrays
i. Array Steering
h. Multipole Radiation
i. Electric Dipole Radiation
ii. Magnetic Dipole and Electric Quadrupole Radiation
i. Integral Equation Approach to Scattering
i. The Magnetic Field Integral Equation for a Perfectly Conducting Target
ii. The Weak-Scatterer and High-Frequency Limits

VI. The Liénard-Wiechert Potentials
a. The Liénard-Wiechert Potentials
b. Fields Due to a charge in Uniform Motion
c. Convection Potential

VII. Accelerating charges
a. Fields of an Accelerating charge
b. Radiation at Low Velocity
c. Acceleration Parallel to Velocity
d. Acceleration Perpendicular to Velocity
e. Bremsstrahlung and Čerenkov Radiation

VIII. Scattering by Particles and Dispersion
a. Scattering by a Free charge
b. Scattering by a Bound charge
c. Volume Scatterers
d. The Kramers-Kronig Relations

Appendix Spherical Waves

D. LABORATORY: None

E. FACULTY CONTACT: B. Borden

DGRE 3/09

Department Guide to Reason and Enlightenment

(DGRE)

PH4354 ADVANCED ELECTROMAGNETIC RADIATION

A. CATALOGUE DESCRIPTION: This course gives an in depth coverage of scattering of electromagnetic radiation in the microwave to optical region, from randomly fluctuating atmosphere, which has its most significant application in the high energy laser weapon program. PREREQUISITES: PH3352, PH3991

B. TEXT BOOK: The course is based on "Jackson Classical Electrodynamics 3rd Ed." And on "Ishimaru, Wave propagation and Scattering in Random Media," but excerpted notes of the instructor will be provided.

C. COURSE CONTENT:

1. The Inhomogeneous wave equation, Green function and solution of the inhomogeneous wave equation.
2. Electromagnetic Fields due to localized harmonically oscillating sources, Dipole radiation, Spherical Harmonic Function representation of Green Function and Plane Waves.
3. Scattering from single dielectric and perfectly conducting spheres at long wave length, Rayleigh scattering, Mie scattering.
4. First Order Multiple Scattering of continuous and pulsed waves from tenuously distributed scatterers, scattering cross section and temporal correlation functions
5. Description of wave scattering in continuous medium with weak random fluctuations of the scattered field.
6. Line-of-Sight propagation of plane waves through weakly turbulent medium and spectral representation of wave amplitude and phase functions.
7. Propagation of waves in strong turbulent medium, Mutual Coherence Function, Temporal Frequency spectra and Modulation Transfer Function.

D. LABORATORY: None

E. FACULTY CONTACT:

DGRE 1/02

Department Guide to Reason and Enlightenment

(DGRE)

PH4454 SONAR TRANSDUCER THEORY AND DESIGN (4-2)

A. CATALOG DESCRIPTION: A treatment of the fundamental phenomena basic to the design of sonar transducers, specific examples of their application and design exercises. Topics include piezoelectric, magnetostrictive, and hydromechanical effects. Laboratory includes experimants on measurement techniques, properties of transducer materials, characteristics of typical Navy transducers, and a design project. A field trip to visit one or more transducer manufacturers is normally scheduled during the course. PREREQUISITES: PH3452 (may be taken concurrently).

B. SUGGESTED TEXT: O.B. Wilson, *An Introduction to Theory and Design of Underwater Transducers*.

C. COURSE CONTENT:

	Topics	Hours
a.	Introduction to and survey of transducer mechanisms and materials	2
b.	Analysis of transducers using four-terminal network theory and equivalent circuits; impedance and mobility analogies; equivalent circuit of radiation field; electrical impedance and admittance analysis	8
c.	Applications of network theory to a simple electric field (reciprocal) transducer	2
d.	Applications of network theory to simple magnetic field (anitreciprocal) transducer; coping with antireciprocal transducer	2
e.	Coupled acoustic networks; diffraction constant; reciprocity calibration; array modeling	3
f.	Properties of elastic, piezoelectric, ferroelectric, and magnetostrictive materials; linearized constitutive properties	6
g.	Equivalent circuits for typical piezoelectric vibrator elements	8
h.	Low frequency projectors, e.g., Hemholtz resonator flextensional hydroacoustics	2
i.	Limitations on sonar projectors performance; modern power density materials: Terfenol & PMN	2
j.	Hydrophones; modern composite piezoelectric hydrophone materials	4
k.	Fiber-optic transducers	4

D. LABORATORY: Laboratory includes experiments on measurement techniques, properties of transducer materials, characteristics of typical Navy transducers, and a design project. A field trip to visit one or more transducer manufacturers is normally scheduled during the course.

E. FACULTY CONTACT: Prof. Steve Baker

Revised 4/00

PH4455 SOUND PROPAGATION IN THE OCEAN (4-0)

A. CATALOG DESCRIPTION: An advanced treatment of the subject, topics include: reflection of spherical waves from ocean boundaries; normal mode propagation of sound; inhomogeneous wave equation and the point source in cylindrical coordinates; shallow water channel with fluid and solid bottoms; the deep sound channel and the WKB approximation; range-dependent channels; adiabatic normal modes and the parabolic equation; multi-path propagation; application to Arctic ocean acoustics. PREREQUISITE: PH3452 or consent of instructor.

B. RECOMMENDED TEXT: Jensen, Kuperman, Porter and Schmidt, Computational Ocean Acoustics.

C. COURSE CONTENTS

TOPICS	APPROX. HRS.
1. The ocean environment as an acoustic medium	2
2. The acoustic wave equation	2
3. Homogeneous media	2
4. Point sources and distributed sources	3
5. Reciprocity	1
6. Plane wave decomposition	2
7. Plane wave boundary interactions	2
8. Spherical wave boundary interactions	4
9. Ray methods; the eikonal and transport equations	4
10. Wave number integration techniques	1
11. Normal mode methods; separation of variables	4
12. Mode cutoff and modal group speeds	2
13. Coupled modes and the adiabatic approximation	2
14. Parabolic equation methods	4
15. Broadband analysis; pulse propagation	2
16. Plane wave beamforming; match filtering	3
17. Matched field processing; source localization	4

D. LABORATORY: None

E. FACULTY CONTACT: K. SMITH

DGRE 4/00

Department Guide to Reason and Enlightenment

(DGRE)

PH4459: Nonlinear Oscillations and Waves (4-0)

A. CATALOG DESCRIPTION. This is a self-contained course that emphasizes theory, classroom demonstrations, physical intuition, and applications of nonlinear oscillations and nonlinear waves. Subjects include the following: (i) Nonlinear oscillations: free motion, driven motion (direct, parametric, and maintained drives), quasiperiodicity, and chaos. (ii) Nonlinear dispersive waves (e.g. flexural waves on bars and plates, optical waves in fibers, and surface waves on water): self-interaction, wave-wave scattering, wave turbulence, and solitons. (iii) Nonlinear dispersionless waves, with concentration on acoustics: distortion, shock waves, parametric arrays, radiation pressure, levitation, jetting and streaming, acoustic cavitation, and sonoluminescence. Prerequisites: PH1121 and differential equations.

<u>subject</u>

nonlinear oscillators
chaos
nonlinear dispersive waves
solitons
nonlinear distortion and shocks in acoustics
interaction of sound with sound (including parametric arrays and absorption of sound by noise)
acoustic radiation pressure
acoustic streaming
acoustic cavitation and sonoluminescence

Prof. Bruce Denardo
Summer 2003

Department Guide to Reason and Enlightenment

(DGRE)

PH4656 QUANTUM MECHANICS (4-1)

A. COURSE DESCRIPTION: Free particles and wave packets, the uncertainty principle, Schrodinger equation, eigen states and eigen functions, stationary and scattering states, identical particles and the exclusion principle, atomic energy levels, quantum theory of angular momentum, hydrogen atom, coupling of angular momentum with spin, the periodic table, nuclear structure and radioactivity; fission and fusion, time independent perturbation theory, time dependent perturbation theory; selection rules for dipole radiation, magnetic effects (MRI, GMR etc.), quantum computing. PREREQUISITES: PH2652, PH3152, PH3991

B. RECOMMENDED TEXT: Richard M. Liboff, Introduction to Quantum Mechanics (4^{th} Edition)

C. COURSE CONTENT:

	Approx. Hrs.
1. Free particles and wave packets	4
2. Eigen states and eigen functions	4
3. Identical particles and exclusion principle	2
4. Quantum theory of angular momentum and hydrogen atom	8
5. Coupling of angular momentum with spin	4
6. Periodic table	2
7. Perturbation theory and dipole radiation	8
8. Magnetic effects (MRI, GMR etc.)	4
9. Quantum computing	2
10. Nuclear structure and radioactivity; fission and fusion	6

D. LABORATORY: Problem Sessions

E. COURSE COORDINATOR: G. Karunasiri

Revised: 8/03

Department Guide to Reason and Enlightenment
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CS4670/PH4670, Quantum Computing, Spring 2009

A. **Catalog Description.** This inter-disciplinary survey course explores the evolution and current direction of quantum computing technology. Topics include quantum circuits, quantum algorithms (including factoring and search), and quantum key distribution. You will learn to think critically about the tradeoffs of this evolving technology. Prerequisites: familiarity with basic notions of computing, quantum theory, and linear algebra, consistent with the material covered in CS3000, PH2652, MA3042 or PH3991.

B. **Recommended Text:** Nielsen and Chuang, Quantum Computation and Quantum Information.

C. **Course Content**

1. Introduction

- History of quantum computing and quantum key distribution
    - Richard Feynman
    - Peter Shor
- Fundamental Terminology
- Why are quantum computers more powerful than classical computers?

2. Foundational Physics of Quantum Computing

- Birefringence: calcite crystal demo
- Superpositions and parallelism
- Qubits vs. classical bits [Mullins01]
- The Bloch sphere
- The no cloning theorem
- Quantum entanglement [Salart08] and teleportation
- Quantum error correction and quantum information theory
- Applets [http://jquantum.sourceforge.net/]
- “Uncollapsing” [Katz08]

3. Quantum Computer Architecture I

- How might a quantum computer work?
    - How to represent the algorithm and data?
    - How to load the machine?
    - How to run the machine?
    - How to extract the result?
    - What is the interface to the quantum computer?
- Why is it hard to extract the answer?

4. Quantum Computer Architecture II

- Quantum circuits, gates, and wires [Oskin02] [Oskin03]
- Why does quantum computing need reversible computation?
- Multiple qubit gates
- Why does quantum computing *need* complex numbers?

5. *Quantum Algorithms I*

- Shor’s Algorithm [Shor96]
    - Why is Shor’s Algorithm a problem for public key cryptography?
    - How does classical factoring work? [Schneier95]
    - What is the Quantum Fourier Transform and how is it used to factor?
    - What is the largest number factored so far on a quantum computer?

6. Quantum Algorithms II

- Grover's Algorithm [Grover96]
  - How does classical search work?
- Simulation of quantum mechanical systems

7. Quantum Algorithms III

- Why is it hard to design quantum algorithms? [Shor04]
- What are the quantum computational complexity classes?
- What are the limitations of quantum algorithms? [Aaronson08] [Day07]
- What is the price of quantum error correction?
- What is quantum information theory?
- What is distributed quantum computation?
- Can we connect today's puny quantum computers together to form a more powerful computer? [Curcic04]

8. Physical Implementations of Quantum Computers

- Ways of creating qubits in the physical world [Ross08]
  - Ion traps [Stick07]
  - Quantum dots [Vandersypen07]
  - Nuclear magnetic resonance [Vandersypen01]
- Who has already built a quantum computer, and what can it do?

9. *Quantum Key Distribution I*

- Photons, birefringence, and polarization
- Review of classical key distribution
- The physics of QKD
- QKD algorithms

10. Quantum Key Distribution II

- Physical implementations of QKD
  - Magic Q
  - NSA
  - QKD for ships – 2003 NPS M.S. Thesis
- QKD Protocols [Haitjema07] [Kuhn03] [Das08]
- Information assurance issues

11. Student Presentations

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PH4760 SOLID STATE PHYSICS (4-0)

A. Catalog Description: Fundamental theory dealing with solids: crystals, binding, energy, lattice vibration, dislocations, mechanical properties, free electron theory, properties of semiconductors and insulators, magnetism. PREREQUISITES: PH3655, PH4656, and PH3782.

B. Recommended Text: C. Kittel, Introduction to Solid State Physics, or equivalent.

C. Course Contents

Topic	Approx. hours
1. Crystal structures	5
2. Diffraction from periodic structures	5
3. Classification of solids; bonding	3
4. Lattice vibrations	4
5. Thermal properties	3
6. Metallic behavior & free electron gas	6
7. Band theory	6
8. Semiconductors	6
9. Magnetism	4

D. LABORATORY: None

E. FACULTY CONTACT: G. KARUNASIRI

DGRE: 12/97