Republic of the Philippines
OFFICE OF THE PRESIDENT
COMMISSION ON HIGHER EDUCATION

CHED MEMORANDUM ORDER (CMO)
No. 20
Series 2007

SUBJECT: MINIMUM POLICIES AND STANDARDS FOR BACHELOR OF SCIENCE IN PHYSICS (BS PHYSICS) AND BACHELOR OF SCIENCE IN APPLIED PHYSICS (BS APPLIED PHYSICS)

In accordance with the pertinent provisions of Republic Act (RA) No. 7722, otherwise known as the "Higher Education Act of 1994," and for the purpose of rationalizing the undergraduate physics education in the country with the end view of keeping apace with the advances in the discipline and the demands of globalization, the following rules and guidelines are hereby adopted and promulgated by the Commission.

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ARTICLE I
INTRODUCTION

Section 1

Physics is the foundation of all Natural Sciences. It is the science of matter, energy, space, and time. Physics is progressing constantly and covers topics from man-made to natural, from the very small to the very large, from designing and fabricating new instruments to observe and utilize properties of these objects to formulating theories to explain their properties.

Applied physics is intended for a particular technological or practical use. Applied physics is rooted in the basic concepts of the physical sciences but is concerned with the utilization of scientific principles in practical devices and systems, and in the application of physics in other areas of science.

ARTICLE II
AUTHORITY TO OPERATE

Section 2

All private higher education institutions (PHEIs) intending to offer the Bachelor of Science in Physics or the Bachelor of Science in Applied Physics must secure proper authority from the Commission in accordance with existing rules and regulations. State universities and colleges (SUCs), and local colleges and universities should likewise strictly adhere to the provisions in this policies and standards.

ARTICLE III
PROGRAM SPECIFICATIONS

Section 3 Degree Name

The degree program herein shall be called Bachelor of Science in Physics/Bachelor of Science in Applied Physics.

Section 4 Program Description

The undergraduate degree program in physics/applied physics should be a balance between a holistic general education program and a substantial physics/applied physics curriculum.

4.1 Objectives

The program leading to the degree of B.S. Physics/Applied Physics shall provide the students with a comprehensive and rigorous training in physics as a foundation for careers in pure and applied physics or interdisciplinary sciences. The program would be sufficient to enable the students to pursue areas such as:

- Advanced physics research
- University physics teaching
- Graduate studies
- Employment in physics-related jobs in business, industry or the government

The applied physics program is specifically designed for those who intend to use the principles and methods of physics to other fields or to the solutions of practical problems of society such as those arising in the industries, health or public service.

4.2 Specific professions/careers/occupations or trades that BS Physics/Applied Physics graduates may go into.

A bachelor's degree in physics/applied physics will prepare the graduates for work in private and government research and service institutes, academic units, media and industry. It will also prepare them for graduate studies.

Section 5 Allied Programs

Physics/Applied Physics is closely related to the fields of engineering (electrical, mechanical, chemical), materials science, mathematics, physical chemistry, meteorology and biophysics.

ARTICLE IV
COMPETENCY STANDARDS

Section 6 Competency Standards

Graduates of a BS Physics/Applied Physics program must be able to:

1. Apply mathematical, computational and experimental methods in solving physical problems;
2. Synthesize and effectively communicate scientific information; and
3. Apply scientific reasoning to arrive at decisions.

ARTICLE V
CURRICULUM

Section 7 Curriculum Description

The curriculum for the undergraduate physics program should contain at least 69 units of core physics and mathematics, 12 units of physics electives, 6 units of free electives, 6 units of special project and 51 units of general education.

The curriculum for the undergraduate applied physics program should contain at least 60 units of core physics and mathematics, 21 units of electives geared towards a particular field of concentration, 6 units of free electives, 6 units of special project and 51 units of general education.

The following program is envisioned to be the recommended university-level program for a Bachelor of Science in Physics/Applied Physics in the Philippines with the objectives stated above. The program is designed to prepare students to take advantage of the next technological wave.

It is realized that physics departments of the different schools will have their particular strengths and orientation. The elective courses will allow for flexibility and accommodate the special interests of the various departments.

Section 8 Curriculum Outline

The minimum requirements for a Bachelor of Science in Physics and a Bachelor of Science in Applied Physics are outlined in Table 1 below.

Table 1. Curriculum outline for BS Physics/BS Applied Physics programs.

PROGRAM	SECTION	UNITS
BS Physics		
	General Education Courses	51
	Core Courses	69
	Physics Electives	12
	Free Electives	6
	Special Project	6
	Total units	144
BS Applied Physics		
	General Education Courses	51
	Core Courses	60
	Specialization	21
	Free Electives	6
	Special Project	6
	Total units	144

Section 9 General Education Courses (GEC)

GE courses are based on the required 51 units in GEC B (CM 4, series 1997). The list of GE courses is in Table 2.

Table 2. GE courses and corresponding units.

FIELDS OF STUDY	SPECIFIC COURSES	UNITS	
1. Language and Humanities	English	6	**21**
	Filipino	6	
	Humanities subjects (e.g. Literature, Art, Philosophy)	9	
2. Mathematics, Natural Sciences and Information Technology	Mathematics	6	**15**
	Natural Science	6	
	Elective e.g. Information Technology/ Science, Technology and Society (STS)	3	
	Note: The GE Natural Science must include at least a Chemistry course.		

Table 2 continued

FIELDS OF STUDY	SPECIFIC COURSES	UNITS	
3. Social Sciences	Consist of subjects such as Political Science, Psychology, Anthropology, Economics, History and the like, provided that the following topics are taken up in appropriate subjects: Taxation and Land Reform, Philippine Constitution, Family Planning and Population Education.	12	**15**
	Life and Works of Rizal (*Mandated Subject*)	3	
	TOTAL		**51**

Section 10 Core Courses

The following selection are the minimum required core courses based on the understanding of the Technical Committee for the Physics discipline of what basic physics students of the program should know and to what branches of the discipline they should be exposed. A department may go beyond the required core courses depending on the strength and availability of resources in the institution.

Table 3. List of core courses for the BS Physics and BS Applied Physics programs.

PROGRAM	COURSES	UNITS
BS PHYSICS		
	Mathematics and Mathematical Physics Core	**19**
	a. Calculus	10
	b. Differential Equations	3
	c. Mathematics Physics	6
	Physics Core	**50**
	a. Advance Laboratory	3
	b. Computational Methods (with lab)	4
	c. Electromagnetic Theory I, II	6
	d. Electronics (with one unit lab)	4
	e. General Physics (with 3 units of lab)	12
	f. Modern Physics	3
	g. Optics	3
	h. Quantum Mechanics	3
	i. Solid State Physics	3
	j. Statistical and Thermal Physics	3
	k. Theoretical Mechanics I, II	6
	Total Units	**69**
BS APPLIED PHYSICS		
	Mathematics and Mathematical Physics Core	**19 units**
	a. Calculus	10
	b. Differential Equations	3
	c. Mathematics Physics	6
	Physics Core	**41 units**
	a. Advanced Laboratory	3
	b. Advanced Mechanics	3
	c. Computational Methods (with lab)	4
	d. Electromagnetic Theory I, II	6
	e. Electronics (with one unit lab)	4

Table 3 continued

PROGRAM	COURSES	UNITS
	f. General Physics (with 3 units of lab)	12
	g. Modern Physics	3
	h. Quantum Mechanics	3
	Statistical and Thermal Physics	3
		60 units

Section 11 Suggested Electives/Specialization

Physics electives may be chosen from the suggested courses listed in Table 4. The courses for specialization in the BS Applied Physics program can be selected from the list of elective courses for BS Physics and courses in engineering, or allied fields. Selected courses in the specialization must show a field of concentration. The unit must have a strong faculty line-up in the specialization program.

Table 4. List of elective courses for the BS Physics and BS Applied Physics programs.

PROGRAM	COURSES	UNITS
BS PHYSICS		**12**
	a. Advanced Electronics	
	b. Advanced Mathematical Physics Courses	
	c. Advanced Statistical Physics	
	d. Astrophysics and Planetary Physics	
	e. Atmospheric Physics	
	f. Biophysics	
	g. Complex Systems	
	h. Computers and Computational Methods	
	i. Condensed Matter Physics	
	j. Crystallography	
	k. Environmental Physics	
	l. Fluid Mechanics	
	m. General Relativity	
	n. Geophysics	
	o. Instrumentation Physics	
	p. Laser Physics	
	q. Medical and Health Physics	
	r. Nuclear and Particle Physics	
	s. Optics	
	t. Physics and Society	
	u. Physics Education	
	v. Physics of Energy	
	w. Physics Seminar	
	x. Plasma Physics	
	y. Special Topics in Physics	
BS APPLIED PHYSICS		**21**
	a. Specialization	

Section 12 Free Electives (6 units)

Realizing that the emerging fields of science are interdisciplinary in nature, the 6 units of free electives will allow the students to freely enroll outside physics.

Section 13 Special Project (6 units)

The special project is an integration of all skills and knowledge obtained in the BS degree. This component could be a thesis, special project, on-the-job training (OJT) or any combination. HEIs shall have the prerogative to choose a mode of implementing this requirement based on the available resources within the institution and opportunities for collaboration with suitable outside organizations.

It is highly recommended that for those with thesis option programs, the department must have research facilities in at least one area of concentration.

Section 14 Sample Program of Study (Minimum Units)

The program of study herein is only an example. HEIs may use this sample and modify it according to its needs. They may also add other preferred courses.

14.1 Suggested Program of Study for BS Physics (145 units)

Tables 5 and 6 below give the recommended programs of study. HEIs may adhere to these, or when necessary, modify the sequencing of courses.

Table 5. Recommended sequence of courses in the BS Physics program. (Abbreviations used: Lec-Lecture, Lab-Laboratory, GE-General Education, PE-Physical Education, NSTP-National Service Training Program)

YEAR	First Semester				Second Semester			
	Descriptive Title	Units			Descriptive Title	Units		
		Lec	Lab	Total		Lec	Lab	Total
I	Algebra and Trigonometry (GE1&2)	6		6	Calculus I	5		5
	GE 3	3		3	Physics I	3	1	4
	GE 4	3		3	General Chemistry (GE 7)	3	1	4
	GE 5	3		3	GE 8	3		3
	GE 6	3		3	GE 9	3		3
	PE I		(2)	(2)	PE II		(2)	(2)
	NSTP		(3)	(3)	NSTP		(3)	(3)
	Total	18		18	Total	17	2	19
II	Calculus II	5		5	Mathematical Physics	3		3
	Physics II	3	1	4	Physics III	3	1	4
	GE 10	3		3	Differential Equations	3		3
	GE 11	3		3	Electronics	3	1	4
	GE 12	3		3	GE 13	3		3
	PE III		(2)	(2)	PE IV		(2)	(2)
	Total	17	1	18	Total	15	2	17

Table 5 continued

YEAR	First Semester				Second Semester			
	Descriptive Title	Units			Descriptive Title	Units		
		Lec	Lab	Total		Lec	Lab	Total
III	Mathematical Physics II	3		3	Mechanics II	3		3
	Mechanics I	3		3	Electromagnetism II	3		3
	Electromagnetism I	3		3	Computational Physics	3	1	4
	Modern Physics	3		3	Advanced Laboratory	3		3
	GE 14	3		3	Quantum Mechanics	3		3
	GE 15	3		3	GE 16	3		3
	Total	18	0	18	Total	18	1	19
IV	Optics	3		3	Electives 2	3		3
	Statistical Mechanics	3		3	Electives 3	3		3
	Solid State	3		3	Electives 4	3		3
	Elective 1	3		3	Special Project II	3		3
	Free Elective 1	3		3	Free Elective 2	3		3
	Special Project I	3		3	GE 17	3		3
	Total	18	0	18	Total	18	0	18

14.2 Suggested Program of Study for BS Applied Physics (145 units)

Table 6. Recommended sequence of courses in the BS Applied Physics program. (Abbreviations used: Lec-Lecture, Lab-Laboratory, GE-General Education, PE-Physical Education, NSTP-National Service Training Program)

YEAR	First Semester				Second Semester			
	Descriptive Title	Units			Descriptive Title	Units		
		Lec	Lab	Total		Lec	Lab	Total
I	Algebra and Trigonometry (GE1&2)	6		6	Calculus I	5		5
	GE 3	3		3	Physics I	3	1	4
	GE 4	3		3	General Chemistry (GE 7)	3	1	4
	GE 5	3		3	GE 8	3		3
	GE 6	3		3	GE 9	3		3
	PE I		(2)	(2)	PE II		(2)	(2)
	NSTP		(3)	(3)	NSTP		(3)	(3)
	Total	18	0	18	Total	17	2	19
II	Calculus II	5		5	Mathematical Physics	3		3
	Physics II	3	1	4	Physics III	3	1	4
	GE 10	3		3	Differential Equations	3		3
	GE 11	3		3	Electronics	3	1	4
	GE 12	3		3	GE 13	3		3
	PE III		(2)	(2)	PE IV		(2)	(2)
	Total	17	1	18	Total	15	2	17

Table 6 continued

YEAR	First Semester				Second Semester			
	Descriptive Title	Units			Descriptive Title	Units		
		Lec	Lab	Total		Lec	Lab	Total
III	Mathematical Physics II	3		3	Specialization 2	3		3
	Mechanics I	3		3	Electromagnetism II	3		3
	Electromagnetism I	3		3	Computational Physics	3	1	4
	Modern Physics	3		3	Advanced Laboratory	3		3
	Specialization 1	3		3	Quantum Mechanics	3		3
	GE 14	3		3	GE 15	3		3
	Total	18	0	18	Total	18	1	19
IV	Specialization 3 & 4	6		6	Specialization 5-7	9		9
	Statistical Mechanics	3		3	Special Project II	3		3
	GE 16	3		3	Free Elective 2	3		3
	Free Elective 1	3		3	GE 17	3		3
	Special Project I	3		3				
	Total	18		18	Total	18	0	18

ARTICLE VI
COURSE SPECIFICATIONS

Section 15 MINIMUM COURSE CONTENTS OF THE PHYSICS COURSES FOR BS PHYSICS AND BS APPLIED PHYSICS PROGRAM

The following course specifications are only for the major courses. HEIs may follow their own course specifications in the implementation of the program but must not be less than those specified for the major courses.

In providing course outlines and reference texts, the Technical Committee for Physics has detailed the breadth, depth and standards of the program.

15.1 INTRODUCTORY GENERAL PHYSICS

The introductory general physics to be taken during the freshman and sophomore years of the B.S. Physics major shall consist of at least nine (9) units of lecture and three (3) units of laboratory covering Classical Mechanics to Modern Physics at the calculus level.

On the other hand, the introductory general physics to be taken during the freshman and sophomore years of the BS Applied Physics major should consist of a three-semester sequence of courses of four (4) units each (3 units lecture, 1 unit lab) at the level of Physics or Fundamentals of Physics by Sears, Zemansky and Young. Corequisite to these is the usual sequence of calculus courses at the level of Calculus with Analytic Geometry by Leithold.

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Young and Freedman. University Physics. Addison Wesley
2. Halliday, Resnick, and Walker. Fundamentals of Physics. John Wiley & Sons
3. Halliday, Resnick, and Krane. Physics. John Wiley & Sons
4. Ohanian. Modern Physics. Prentice Hall
5. Fishbane, Gasiorowicz and Thornton. Physics for Scientists and Engineers. Prentice Hall
6. Crummett and Western. University Physics. McGraw-Hill
7. Serway. Physics for Scientists and Engineers. Saunders
8. Feynman andLeighton/Sands. Lectures in Physics. Addison-Wesley
9. Ford. Classical and Modern Physics Vols. I, II, III. Wiley
10. Tipler. Physics. Worth Publishers

15.2 UPPER DIVISION COURSES

Listed below are the minimum contents of the standard B.S. (Physics) courses starting in the third year. The level of treatment of the courses should be equivalent or similar to those of the accompanying suggested textbooks. For those schools desiring to go beyond the minimum, the suggested optional topics may be incorporated into the requirements.

15.2.1 MATHEMATICS/MATHEMATICAL PHYSICS

a. Vector Analysis

Gradient, divergence, curl, line integrals, surface integrals, volume integrals, divergence theorem, Stoke's theorem, path-independent line integrals, tensors.

b. Matrix Algebra

Inverse, Gauss-Jordan reduction, Hamilton-Cayley theorem, determinants eigenvectors and eigenvalues.

c. Complex Analysis

Complex algebra, Taylor series, Laurent series, integration by method of residues.

d. Differential Equations and Fourier Analysis

Ordinary differential equations, series solutions, Fourier series, orthogonal functions.

e. Probability

Permutations, combinations, elementary probability theory, binomial distribution, Poisson distribution, Gaussian distribution, expectation value and variance.

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Arfken. Mathematical Methods for Physicists Academic Press
2. Courant and Hilbert. Methods of Theoretical Physics, Vols. 1 and 2. Interscience
3. Crummett and Western. University Physics. McGraw-Hill.
4. Feynman, Leighton and Sands. Lectures in Physics. Addison-Wesley

5. Fishbane, Gasiorowicz and Thornton. Physics for Scientists and Engineers (Extended Version). Prentice Hall
6. Ford. Classical and Modern Physics Vols. I, II, III. Wiley
7. Friedberg, Insel, and Spence. Linear Algebra. Prentice Hall
8. Halliday, Resnick, and Walker. Physics. John Wiley & Sons
9. Hassani and Sadri. Foundation of Mathematical Physics. Prentice-Hall
10. Kreyszig. Advanced Engineering Mathematics. John Wiley
11. Kolman. Elementary Linear Algebra. Prentice Hall
12. Landesman and Hestenes. Linear Algebra for Mathematics, Science and Engineering. Prentice Hall
13. Leon. Linear Algebra with Applications. Prentice Hall
14. Morse and Feshbach. Methods of Theoretical Physics. McGraw-Hill
15. Ohanian. Modern Physics. Prentice Hall
16. Serway. Physics for Scientists and Engineers. Saunders
17. Tipler. Physics. Worth Publishers
18. Young and Freedman. University Physics. Addison Wesley
19. Mathews andWalker. Mathematical Methods of Physics. Benjamin
20. Hammermesh. Group Theory and Its Applications to Physical Problems. Addison-Wesley
21. Wybourne. Classical Group for Physicists. Wiley
22. Gradshteyn and Ryzhik. Tables of Integrals, Series and Productions. Academic Press
23. Weinberger. First Course in Partial Differential Equations. Blaisell
24. Selby (ed.). Standard Mathematical Tables. Chemical Rubber Company
25. Churchill and Brown. Complex Variables and Applications. McGraw-Hill
26. Seelley. An Introduction to Fourier Series and Integrals. Benjamin
27. Rainville. Special Functions. Macmillan
28. Birkhoff and Rota. Ordinary Differential Equations. Blaisdell
29. Rainville and Bedient. Elementary Differential Equations. Macmillan
30. Pennisi. Elements of Complex Variables. Holt, Rinehart and Winston
31. Kolman. Elementary Linear Algebra. Macmillan
32. Feller. Introduction to Probability Theory and Its Applications, Vols. 1 and 2. Wiley
33. Herstein. Topics in Algebra. Wiley
34. Buck. Advanced Calculus. McGraw-Hill
35. Georgi. Lie Algebras in Particle Physics. Perseus Books Group
36. O'Raifeartaigh. Group Structure of Gauge Theories. Cambridge Univ. Press.
37. Leithold. Calculus with Analytic Geometry. Harper and Row.
38. Blanchard and Delaney. Differential Equations. Thomson Publishing

15.2.2 THEORETICAL MECHANICS

15.2.2.1 THEORETICAL MECHANICS I

a. One-Dimensional Motion

Newton's second law as a second order differential equation and its solutions momentum and energy theorems, potential energy, harmonic oscillator (simple, damped and forced), stable and unstable equilibrium, velocity-dependent resistance, terminal velocity.

b. Planar, Three-Dimensional and Constrained Motion

Projectile motion (including air resistance), conservative forces, existence of potential energy function, constrained motion, simple pendulum.

c. Central Forces and Gravitation

Conservation of angular momentum, orbits in a central field, Kepler's laws, stability of circular orbits, orbital precession, Rutherford scattering, cross-sections.

d. Theory of Small Oscillations

Stability, normal frequencies and normal coordinates, forced variations.

15.2.2.2 THEORETICAL MECHANICS II

a. Moving Coordinate Systems

Translation and rotation of coordinate systems, Coriolis force, effects of the earth's rotation, Foucault pendulum.

b. Systems of Particles

Center of mass, linear momentum, kinetic energy, angular momentum, two-body systems and reduced mass, collisions, variable mass dynamics (rockets, etc.).

c. Motion of Rigid Bodies

Angular momentum, moment of inertia, rotation about a fixed axis, laminar motion, inertia tensor, principal axes, Euler's equations, gyroscopic precession.

d. Lagrangian-Hamiltonian Formulation

Generalized coordinates and generalized moments, calculus of variation and the principle of at least action, Lagrange's equation, constants of motion and ignorable coordinates, Hamilton's equations.

e. Relativistic Dynamics

Lorentz transformation, transformation of velocities, relativistic momentum, mass-energy relation, four-vectors, relativistic collisions.

f. Optional

Mechanics of continuous media, canonical transformation, Hamilton-Jacobi theory, Lagrangian-Hamiltonian formulation of continuous systems and fields.

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Marion. Classical Dynamics of Particles and Systems. Academic Press
2. Symon. Mechanics. Addison-Wesley
3. Fowles. Analytical Mechanics. Holt, Rinehart and Winston
4. Olsson and Berger. Classical Mechanics: A Modern Perspective. Mc Graw Hill
5. Kossler and Greer. Classical Mechanics with Maple
6. Goldstein. Classical Mechanics. Addison-Wesley
7. Landau and Liftshitz. Mechanics. Pergamon
8. Desloge. Classical Mechanics Vols. 1 and 2. Wiley-Interscience.
9. Sudarshan and Mukunda. Classical Dynamics: A Modern Perspective. Wiley

10. Kleppner and Kolenkaw. An Introduction to Mechanics

15.2.3 ELECTROMAGNETIC THEORY

a. Electrostatics

Superposition, Gauss' law, solutions of Laplace's equation, separation of variables, Legendre polynomials, spherical and cylindrical harmonics, methods of images, dielectrics and polarization, boudnary-value problems involving dielectrics, microscopic theory of dielectrics, electrostatic energy, capacitance.

b. Electric Current (Optional for BS Physics)

Equation of continuity, Ohm's law, DC circuits, conductivity, theory of electric conduction in metals.

c. Magnetism

Biot-Savart law, Ampere's law, vector potential, magnetic properties of matter, magnetization, hysteresis, diamagnetism, paramagnetism, ferromagnetism, magnetic energy.

d. Maxwell's Equations

Maxwell's equations, electromagnetic energy, Poynting vector and wave equation.

e. Electromagnetic Radiation (Optional for BS Applied Physics)

Electromagnetic waves in conducting and nonconducting media, reflection and refraction of electromagnetic waves, waveguides and radiation.

f. Optional (Optional for BS Applied Physics)

Lienard-Wiechert potentials, radiation field of a uniformly moving point charge, accelerated point charge, magnetohydrodynamics and plasma physics. Covariant Formulation: Special relativity, four-vectors, tensors, electromagnetic field tensors, covariant form of electromagnetic equations, transformation of electromagnetic fields and potentials.

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Reitz, Milford and Christy. Foundations of Electromagnetic Theory. Addison-Wesley
2. Corson and Lorraine. Electromagnetic Fields and Waves. W. H. Freeman
3. Marion and Heald. Classical Electromagnetic Radiations. Academic Press
4. Krauss. Electromagnetics. McGraw Hill Book Company
5. Freeman and Topan. Introduction to Electromagnetic Fields and Waves.
6. Landau and Lifshitz. The Classical Theory of Fields. Pergamon
7. Landau and Lifshitz. Electrodynamics of Continuous Media Pergamon
8. Zahn. Electromagnetic Field Theory: A Problem-Solving Approach. Wiley
9. Lerner. Problems and Solutions in Electromagnetic Theory Wiley
10. Portis. Electromagnetic Fields: Sources and Media. Wiley
11. Griffiths. Introduction to Electrodynamics.

15.2.4 MODERN PHYSICS

a. Relativity (Optional for BS Applied Physics)

Lorentz transformations, transformation of velocities, length contraction, time dilation, covariant formulation of mechanics and electromagnetic theory, relativistic collisions and conservation of four-momentum, Compton effect, Dopler shift.

b. Special Relativity

Lorentz transformation, time dilation, length contraction, transformation of velocities, relativistic momentum and energy, Compton effect, red and blue shifts, four-vectors.

c. Old Quantum Theory

Blackbody radiation, photoelectric effect, Bohr theory, Bohr-Somerfeld quantization theory.

d. Quantum Mechanics (Theory)

de Broglie waves, Schroedinger's equation, potential well, harmonic oscillator, angular momentum, hydrogen atom, multi-electron atoms, Pauli's exclusion principle.

e. Quantum Mechanics (Applications)

X-rays, molecules, condensed matter, lasers, nuclei and elementary particles.

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Tipler. Foundations of Modern Physics. Worth
2. Eisberg and Resnick. Quantum Physics of Atoms
3. Beiser. Concepts of Modern Physics. McGraw Hill
4. Gasiorowicz. The Structure of Matter: A Survey of Modern Physics. Addison-Wesley
5. Krane. Modern Physics.Wiley

15.2.5 QUANTUM MECHANICS

a. Quantum Mechanics

Bohr-theory—modifications and difficulties, de Broglie waves, uncertainty relations, wavepackets, observables, expectation values, eigenfunctions and eigenvalues, time evolution, stationary states, particle in a rigid box, barrier penetration, harmonic oscillator, perturbation theory.

Angular momentum and spin, hydrogen atom, identical particles, multiparticle system, Pauli exclusioni principle, multi-electron atoms, transition rates, selection rules, scattering theory.

b. Optional

Semi-classical theory of radiation, Dirac equation.

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Saxon. Elementary Quantum Mechanics. Holden-Day
2. McGervey. Introduction to Modern Physics. Academic Press
3. Liboff. Introductory Quantum Mechanics. Holden-Day, Inc.
4. Gasiorowicz. Quantum Physics. John Wiley & Sons
5. Greiner. Quantum Mechanics-Symmetric. Springer
6. Griffith. Introduction to Quantum Mechanics
7. Goswami. Quantum Mechanics
8. Sakurai. Modern Quantum Mechanics.
9. Eisberg and Resnick. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles. Wiley
10. Dicke and Wittke. Introduction to Quantum Mechanics. Addison-Wiley
11. Merzbacher. Quantum Mechanics. Wiley
12. Schiff. Quantum Mechanics. McGraw-Hill
13. Messiah. Quantum Mechanics Vols. 1 and 2. Interscience
14. Dirac. The Principles of Quantum Mechanics. Oxford
15. Landau and Lifshitz. Quantum Mechanics-Non-Relativistic Theory. Pergamon
16. Tipler. Foundations of Modern Physics. Worth
17. Constantinescu and Magyari. Problems in Quantum Mechanics. Pergamon
18. Flugge. Practical Quantum Mechanics Vols. 1 and 2. Springer-Verlag
19. Amein. Nonrelativistic Quantum Dynamics. Reidel
20. Prugovecki. Quantum Mechanics in Hilbert Space. Academic Press
21. Davydov. Quantum Mechanics. Addison-Wesley
22. Cohen-Tannoudji. Quantum Mechanics Vols. 1 and 2 Wiley
23. McGervey. Introduction of Modern Physics. Academic Press
24. Gottfried. Quantum Mechanics Vol. 1-Fundamentals. W.A. Benjamin
25. Jordan. Quantum Mechanics in Simple Matrix Form. Wiley
26. Das and Melissinos. Quantum Mechanics: A Modern Introduction. Serdon and Breach
27. Lipkin. Quantum Mechanics. Elsevier
28. Yndurain. Relativistic Quantum Mechanics & Introduction to Field Theory. Springer
29. Aitchison. Relativistic Quantum Mechanics. Macmillan

15.2.6 ELECTRONICS

The electronics course should consist of at least one semester lecture-laboratory classes.

a. Convention and Units (Optional for BS Applied Physics)

Voltage, current, and resistivity, source and load, insulators and conductors, frequency, wavelength, and period, Ohm's law, DC and AC signals, RMS values, attenuation and gain.

b. Passive Devices

Resistors, voltage divider, Thevenin's theorem, Norton's theorem, current and voltage source, capacitors, reactance, charging and discharging, capacitors and resistors in circuits, high/low pass filters, integrators, differentiators, impedance, inductors, resonance, oscillators, bandwidth, and transformers.

c. Nonlinear Devices

Diodes, pn junctions, I-V curves, rectifier circuits, clamps, clippers, Zener diodes, voltage regulation.

d. Transistors

pnp, npn junctions, I-V curves, types of transistors, common transistor configurations: Common emitter, emitter follower, Darlingtons, transistors in parallel/series, current sources/sinks, biasing, signal amplifiers, differential amplifiers, feedback.

e. Operational Amplifiers

Amplifiers: Non-inverting, inverting, summing, difference amplifiers, voltage followers, configurations: differentiator, integrator, current-voltage/voltage-current converters, comparators, peak detectors, active/passive filters, bandwidth, bode plots, single supply operation.

f. Other Integrated Circuits

Voltage regulators, timers, oscillators, voltage to frequency/ frequency to voltage converters.

g. Digital and Analog Electronics

Linear devices and basic linear circuit analysis, diodes, transistors, op-amps, the use of digital components including logic gates, flip-flops, counters, clocks and microcontrollers, and analog to digital conversions.

h. Optional

Instrumentation amplifiers and strain gauges. Sensors: Photodiodes, phototransistors, thermistors

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Horowitz and Hill. The Art of Electronics. Cambridge University Press
2. Smith. Circuits, Devices and Systems
3. Erk. Oscilloscopes: Functional Operation and Measuring Examples. McGraw-Hill

15.2.7 STATISTICAL AND THERMAL PHYSICS

a. Classical Thermodynamics

Laws of thermodynamics, equation of state, work, internal energy, heat capacity, Carnot cycle, change of phase, reversible and irreversible processes, ideal gas, Maxwellan distribution of molecular velocities, Clausius-clapeyron equation, Maxwell's equations, equipartition theorem, Helmholtz function, Gibbs function.

b. Statistical Mechanics

Probability (See I. Mathematics/Mathematical Physics), statistical ensemble, density of states, partition function, identical particles, quantum distribution function, Maxwell-Boltzmann statistics, Bose-Einstein and blackbody radiation, electron gas in metals, lattice vibrations and specific heats of solids, Debye approximation.

c. Optional

Transport theory, irreversible processes, fluctuations, phase transitions.

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Reif. Statistical and Thermal Physics. MacGraw-Hill
2. Kittel and Kroemer. Thermal Physics. Wiley
3. Safran. Statistical Thermodynamics of Surfaces, Interfaces and Membranes. Addison-Wesley
4. Burshtein. Introduction to Thermodynamics and Kinetic Theory of Matter. Wiley
5. Hudson. Thermodynamics: An Advanced Text for Material Scientists. Wiley
6. Callen. Thermodynamics and an Introduction to Thermostatistics. Wiley
7. Stowe. Introduction to Statistical Mechanics and Thermodynamics. Wiley
8. Sears and Salinger. Thermodynamics: The Kinetic Theory of Gases and Statistical Mechanics. Addison-Wesley
9. Pathria. Statistical Mechanics Pergamon
10. Landau and Lifshitz. Statistical Physics. Pergamon

15.2.8 OPTICS

This course covers geometrical and physical optics, which should include: aberrations, optical systems, lasers, scattering, diffraction, Maxwell's equations, absorption, refractive index, spectroscopy, holography, interferometry.

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Hecht and Zajac. Optics. Addison-Wesley
2. Rosai. Optics. Addison-Wesley
3. Jenkins and White. Fundamentals of Optics. McGraw-Hill
4. Fowles. Introduction to Modern Optics. Holt, Rinehart and Winston
5. Born and Wolf. Principles of Optics. Pergamon
6. Ditchburn. Light. Academic Press
7. Klein. Optics. Wiley

15.2.9 SOLID STATE

This course covers crystal structure, reciprocal lattice, phonons, energy band structure, semiconductors, magnetism, and superconductivity.

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Kittel. Introduction to Solid State Physics. Wiley
2. Ashcroft and Mermin. Solid State Physics. Holt, Rinehart and Winston
3. Hans and Lubuth. Introduction to Solid State Physics

15.2.10 ADVANCED LABORATORY

These courses consist of at least one-year laboratory works which should include machine shop practice, measurement techniques, computer work as well as experiments

in advanced optics, atomic and molecular physics, nuclear physics, solid state physics, elementary particles, laser applications, complex systems and low-temperature physics.

Suggested textbooks/references:

The latest editions of the following books are recommended:

1. Malmstadt, Enke and Crouch. Electronics and Instrumentation. Benjamin-Cummings
2. Mellissinos. Experiments in Modern Physics. Academic Press
3. Diefenderfer. Principles of Electronics Instrumentation. Saunders
4. Meiners. Physics Demonstration Experiments Vols. I and II. The Ronald Press

15.2.11 COMPUTATIONAL METHODS (WITH LAB COMPONENT)

Computer programming, numerical analysis, research data processing, simulation and modeling.

15.2.12 OTHERS (Required for the BS Applied Physics Curriculum)

In the BS Applied Physics curriculum, an additional of at least fifteen (15) units of advanced courses in the chosen area of specialization should be taken, excluding the basic pre-requisites for these courses.

Possible areas of specialization are the following:

a. Instrumentation Physics
b. Energy Physics
c. Materials Physics
d. Biophysics
e. Medical and Health Physics
f. Laser Physics
g. Environmental Physics
h. Geophysics and Atmospheric Physics

Section 16 Laboratory Experiments and Equipment

Ideally, students should work in groups of two (2) or three (3). However, a maximum of five (5) students is allowable.

16.1 Introductory Physics Laboratory

Institutions have the prerogative to purchase whole equipment setups or fabricate their own. At the very least, the introductory physics laboratory should have setups for the following experiments:

16.1.1 Mechanics

a. Measurement

- Instruments for measuring length, mass, time
- Error in measurement

b. Motion experiments
- Linear motion (in 1D & 2D)
- Rotational motion
- Periodic motion

c. Newton's Laws
- Translational equilibrium
- Rotational equilibrium

d. Conservation Laws
- Conservation of momentum
- Conservation of energy
- Conservation of angular momentum

16.1.2 Thermodynamics

- Temperature and thermometry
- Thermal expansion
- Heat capacity
- Heat of transformation

16.1.3 Electromagnetism

a. Charge
- Detection
- Electric field

b. DC Circuits and measuring instruments
c. Electromagnetic Induction

16.1.4 Waves and Optics
- Standing waves
- Interference
- Thin lenses
- Reflection and refraction
- Polarization
- Diffraction

16.2 Advanced Physics Laboratory

Ideally, students should work in groups of two (2). For the advanced physics laboratory, the institution must have at least three (3) setups for any of the following recommended experiments:

a. e/m ratio
b. Spectroscopy
c. Millikan oil drop experiment
d. Michelson interferometry
e. Frank-Hertz
f. Radioactive decay

g. Hall effect
h. Photo-conductance
i. Lasers
j. Holography
k. Magnetic resonance
l. X-ray diffraction
m. Electron diffraction

Research grade setups can also be counted as part of the minimum three (3) setups.

ARTICLE VII
GENERAL REQUIREMENTS

Section 17 Program Administration

The minimum qualifications of the head of the unit that implements the degree program are the following:

a. Dean of the unit/college

The dean of a unit/college must be at least a master's degree holder in any of the disciplines for which the unit/college offers a program; and a holder of a valid certificate of registration and professional license, where applicable.

b. Head of the Physics unit/department

The head of the department must be at least a master's degree holder in the discipline for which the unit/department offers a program or a master's degree holder in an allied program identified in the policies and standards; and a holder of a valid certificate of registration and professional license, where applicable.

Section 18 Faculty

18.1 General Requirements

a. As a rule, a master's degree in the discipline or its equivalent is required for teaching in the tertiary level.
b. A minimum of 50% of the full-time faculty must have at least a Master's degree in the discipline or its equivalent

18.2 Qualification of faculty

a. Faculty teaching in a BS Physics/Applied Physics program must have at least a master's degree in physics or from any of the allied fields identified in Section 5.
b. All upper division undergraduate physics courses (3rd year and up) in the BS Physics/Applied Physics program shall be taught by a holder of at least an MS degree in Physics/Applied Physics.

18.3 Full time faculty members

The institution shall maintain 50% of the faculty members teaching in the BS Physics/Applied Physics program as full time. The unit must have at least the following full-time faculty requirements:

a. One (1) Ph.D. degree holder in Physics or allied fields,
b. Three (3) M.S. degree holders in Physics or allied fields, and
c. Education degree holders will not be counted towards the minimum faculty requirement.

18.4 Teaching Load

Faculty teaching in the BS Physics/Applied Physics program shall not be assigned more than four (4) different courses/subjects or preparations within a semester.

18.5 Faculty Development

The institution must have a system of faculty development. It should encourage the faculty to:

a. Pursue graduate studies especially at the PhD level
b. Undertake research activities and to publish their research output
c. Give lectures and present papers in national/international conferences, symposia and seminars
d. Attend seminars, symposia and conferences for continuing education

The institution must provide opportunities and incentives such as:

a. Tuition subsidy for graduate studies
b. Study leave with pay
c. Deloading to finish a thesis or carry out research activities
d. Travel grants for academic development activities such as special skills training and attendance in national/ international conferences, symposia and seminars.
e. Awards & recognition

Section 19 Library

a. Policy

Libraries service the instructional and research needs of the staff and students making it one of the most important service units within an HEI. It is for this reason that libraries should be given special attention by HEI administrators by maintaining it with a wide and up-to-date collection, qualified staff, and communications and connectivity portals.

b. Library Staff

The Head Librarian should: 1) have an appropriate professional training; 2) be a registered librarian; and 3) have a Master's degree.

The library should be: 1) staff with one full time professional librarian for every 1,000 students and 2) a ratio of 1 librarian to 2 staff / clerks should be observed.

c. Library Holdings

Library holdings should conform to existing requirements for libraries. For the BS Physics/Applied Physics program, the libraries must provide at least (20) different titles of introductory or general physics books, including the standard textbooks, at least ten (10) of which have editions no more than eight (8) years old. Also for each upper division physics course offered by the department, the library should have at least five (5) different titles for that field of physics at the appropriate level, and whose editions are less than eight (8) years old.

The HEI is likewise encouraged to maintain periodicals and other non-print materials relevant to physics in order to aid the faculty and students in their academic work. CD-ROMs could complement a library's book collection but should otherwise not be considered as replacement for the same.

d. Internet Access

Internet access is encouraged but should not be made a substitute for book holdings.

e. Space Requirements

At least 126m^2 or approximately 2 classrooms shall be required for the library. It should include space for collections, shelving areas, stockroom, office space for staff and reading area

The library must be able to accommodate 5% of the total enrollment at any one time.

f. Finance.

All library fees should be used exclusively for library operations and development for collections, furnitures and fixtures, equipment and facilities, maintenance and staff development.

g. Networking

Libraries shall participate in inter-institutional activities and cooperative programs whereby resource sharing is encouraged.

h. Accessibility

The library should be readily accessible to all.

i. Office Hours

The library should be open to serve the needs of the users.

Section 20 Facilities and Equipment

a. Laboratory requirements

Laboratories should conform to existing requirements as specified by law (RA 6541, "The National Building Code of the Philippines" and Presidential Decree 856, "Code of

Sanitation of the Philippines"). List of required and recommended equipment are listed in the course specifications above.

b. Classroom requirements

Class Size

(1) For lecture classes, ideal size is 35 students per class, maximum is 50.
(2) For laboratory and research classes, class size shall be 20-25 students per class**. The ideal number of students per set-up is 2-3 in a group.**
(3) Special lectures with class size more than 50 may be allowed as long as the attendant facilities are provided.

c. Educational Technology Centers

The institution should provide facilities to allow preparation, presentation and viewing of audio-visual materials to support instruction.

ARTICLE VIII
ADMISSION AND RETENTION

Section 21

The basic requirement of eligibility for admission of a student to any tertiary level degree program shall be graduation from the secondary level recognized by the Department of Education. Higher education institutions must specify admission, retention and residency requirements. They should ensure that all students are aware of these policies.

ARTICLE IX
TRANSITORY , REPEALING AND EFFECTIVITY PROVISION

Section 22 Transitory Provision

HEIs that have been granted permit or recognition for Bachelor of Science in Physics/ Bachelor of Science in Applied Physics program are required to fully comply with all the requirements in this CMO, within a non-extendable period of five (5) years after the date of its effectivity. State Universities and Colleges (SUCs) and Local Colleges and Universities (LCUs) shall also comply with the requirements herein set forth.

Section 23 Repealing Clause

All CHED issuances, rules or regulations or parts thereof, which are inconsistent with the provisions of this CMO are hereby repealed.

Section 24 Effectivity Clause

This CMO shall take effect fifteen (15) days after its publication in the Official Gazette, or in two (2) newspaper of national circulation. This CMO shall be implemented beginning Academic Year 2008-2009.

For strict compliance.

Pasig City, Philippines March 30, 2007.

FOR THE COMMISSION

CARLITO S. PUNO, DPA
Chairman