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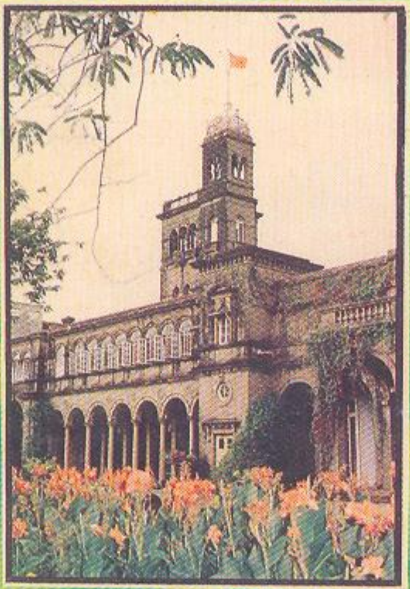
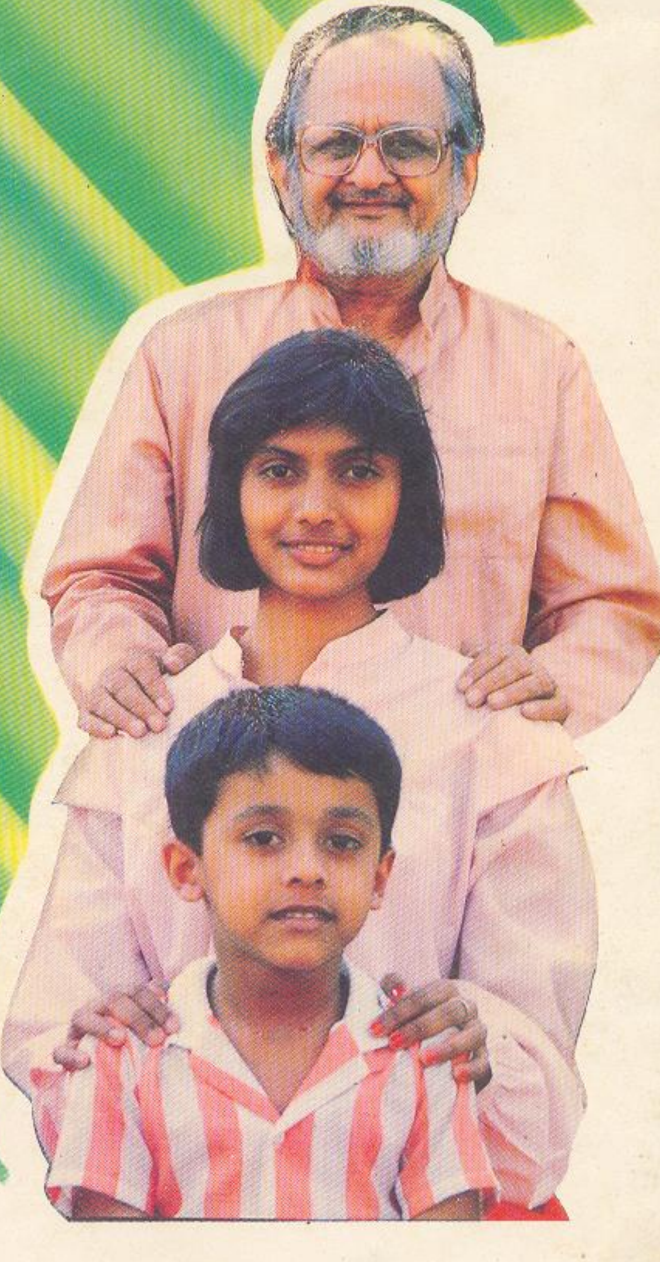
PHYSICS EDUCATION





A LOOK AT SCIENCE EDUCATION

Bridging the gap in physics between school and university • School-university interface in physics • Autonomous Colleges – challenges and opportunities • Importance of a quantitative approach • Physics education in India • Basic requirements to train a physicist.

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On the cover this quarter

Education is a process which evolves continuously with time. Fortunately, India has many educational institutions with high repute and persons with dedication; who maintain this flow. For this purpose such institutions need to cater for the demands of the old and young minds. This is possible only with the preservation of virtuous old traditions of learning and by incorporating new facets to face future challenges. The picture shows the University of Poona building with an eminent educationist, Professor M. R. Bhiday, who still inspires the young minds. This issue is dedicated to his life time mission on innovations in higher education.

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Contents

Five years of *Physics Education* 5

Relation between metal-metal distance, metal-oxygen-metal bridge angle and magnetic exchange in transition metal compounds
A. Syamal 8

A note on the measurement of refractive index in undergraduate laboratory
A. V. Narasimhan & S. K. J. Al-ani 15

FEATURE: A LOOK AT SCIENCE EDUCATION

Bridging the gap in physics between school and university
Lillian C. McDermott 17

School-university interface in physics: Some issues in aiming for continuity in content
Fred Archenhold 25

Autonomous colleges— challenges and opportunities
B. M. Udgaonkar 30

Importance of a quantitative approach in understanding concepts in physics
A. W. Joshi & A. D. Tillu 39

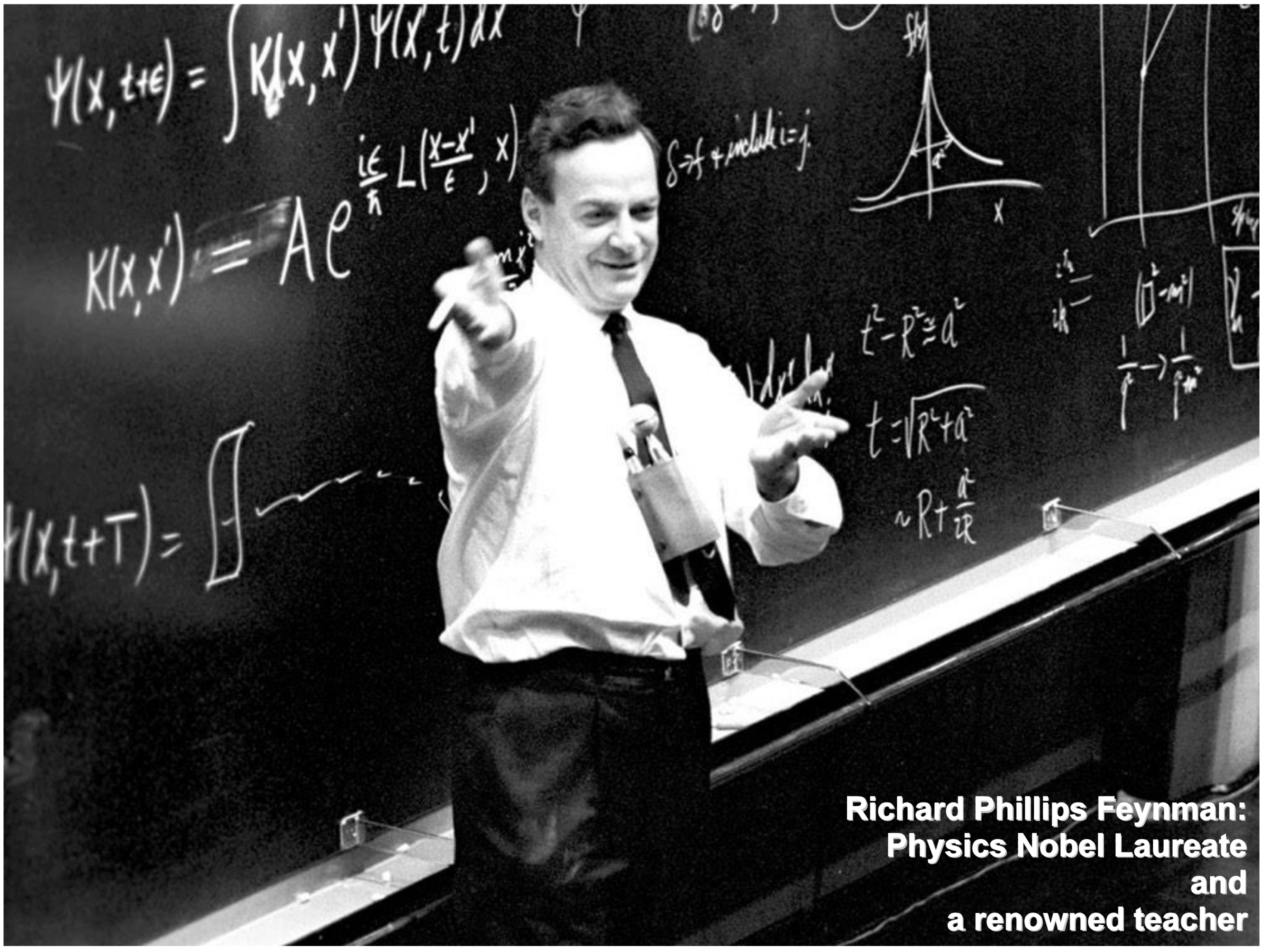
Physics education in India—challenges and opportunities
D. P. Khandelwal 44

Basic requirements to train a physicist
Syed Arif Kamal & Khursheed A. Siddiqui 53

Letters to the Editor (52); Open University education (62); News and Views (63); Books (76); Problem Section (77); How to submit a well written manuscript in proper format (78); Molecular electronics (79).

Basic Requirements to Train a Physicist

The future of Pakistan depends on an adequate training of physicists; we need to prepare them for careers in industry, research and teaching. They should have a thorough understanding of the basic principles of physics and must be able to apply them in practical situations. Our curriculum should → prepare them to handle standard texts in electrodynamics, classical mechanics, statistical physics, quantum mechanics and applied mathematics. To achieve this goal the students need to be highly motivated and should develop habits of creative thinking.



Richard Phillips Feynman: Physics Nobel Laureate and a renowned teacher

Albert Einstein: Imagination is more Important than knowledge

Syed Arif Kamal and Khusheed Athar Siddiqui

Basic requirements to train a physicist

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Abstract

Since the future progress of Pakistan depends on an adequate training of physicists, we need to prepare them for careers in industry, research and teaching. They should have a thorough understanding of the basic principles of physics and must be able to apply them in practical situations. Our curriculum should prepare them to handle standard texts in electrodynamics, classical mechanics, statistical physics, quantum mechanics and applied mathematics. To achieve this goal the students need to be highly motivated and should develop habits of creative thinking and critical analysis. A curriculum is proposed for B.S., M.S. and Ph.D. in physics suitable for the needs of Pakistan. This curriculum also prepares students for graduate and postgraduate studies in foreign universities.

Introduction

In order to keep pace with the technological society of today our educational system must be modified. Students need to be highly motivated by introduction of fresh ideas demonstrating usefulness of physics and presenting physics as fun. Our curriculum should reflect a spirit of inquiry, present, both theory and experiment as processes of successive approximation, not as definite or final knowledge. The students should be able to apply what they have learnt. They should have training in problem solving and should be able to critically analyze a physical situation[1]. They should develop habits of creative thinking, a key ingredient for research.

In a previous work[2] the authors discussed the problems of school and pre-university physics education. In this paper we are proposing a curriculum for B.S. and M.S. Since at present we don't have adequate Ph.D. research facilities in many institutions in Pakistan, our undergraduate training should prepare students for graduate studies in foreign universities.

Current system in Pakistan

A typical student in Pakistan spends ten years in a school, followed by two years in an intermediate college. After that one has a choice either to go to a professional institution (medicine, engineering, business, etc.) or a degree college which offers a B.Sc. course of two years duration. After a B.Sc. some students enroll in a two-year M.Sc. program in one of the universities.

At present there are twenty universities in Pakistan, eleven of which offer M.Sc. programs in physics. The University of Karachi (KU) also enrolls students who have passed their intermediate examinations in a three-year B.Sc. (Honors) program with emphasis on physics. The student selects two minors, one of which must be mathematics. These minors are taught for two years. During the third year all courses are taken in the Physics Department. In addition one has to obtain passing grades in compulsory subjects (Islamic and Pakistan Studies, English and Urdu). Students selecting the honors option are exempted from the first year of M.Sc. courses. KU also has an M.Sc. program in Applied Physics with

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wider orientation towards electronics and solid state physics.

The academic year at KU is divided into two semesters each of four and a half months duration. Each semester credit hour corresponds to fifteen periods of instruction, each period lasting for an hour. A student completes seventy-two credit hours (not including time spent on compulsory subjects) to get a B.Sc. (Hons.) degree and thirty more to get an M.Sc. Those entering with a B.Sc. (Pass) have to complete sixty hours for their M.Sc. degrees. Little time is spent on problem solving, discussions and critical analyses of the physical principles involved. To cite an example, students of B.Sc. (Hons.), Third Year insisted that two balls dropped from the same height—one vertically and the other given a horizontal speed—would not hit the ground at the same time. The one given a horizontal speed would take longer, they said, because it travels a larger distance.

Statement of the problem

The undergraduate and graduate physics training is supposed to prepare students[3]

(a) to serve mainly as staff members in a university physics department, with main emphasis on research but including some teaching obligations;
(b) to serve mainly as staff members in tertiary-level institutions with physics teaching as the main responsibility;
(c) to serve as researchers, administrators and planners in industry, research institutes, government departments and other professions and disciplines.

The existing curriculum does not fulfill these objectives. We need to make physics more attractive. The courses should be changed to meet new goals.

Presently we are giving students an M.Sc. degree without courses in relativity, error analysis and experimental design, history and philosophy of physics. Recent graduates are expected to become absolute masters of classrooms without any previous supervised teaching experience. There is no feedback from students or peers about the performance of a young staff member. Confirmation processes in the colleges and universities are almost automatic. Many teachers are not prepared or motivated to teach even the core courses—courses every physicist must be able to handle.

The problem is compounded by a poor planning of courses. For example, students are expected to study Goldstein: *Classical Mechanics* after a mechanics course roughly at the level of Berkeley Physics Course. How can the students comprehend Goldstein without an intermediate course at the level of Marion: *Classical Dynamics*?

Based on these considerations a curriculum for B.Sc. (Pass), B.Sc. (Hons.), M.Sc. and M.Phil. to fit the twelve semester (six year) program was presented on November 25, 1986, in a seminar The Making of a Physicist organized by Karachi Physics Society. This seminar was attended by teachers from local colleges and faculty from KU. Special emphasis was given to general physics, electromagnetism, mechanics and statistical and thermal physics, which comprise core courses. It was suggested that laboratory experiments should correspond to the theory courses taught.

Based on the recommendations of this group a modified version is prepared. The following section describes the details.

Proposed curriculum

Our goal is to present physics as an integrated intellectual activity, not as a set of mechanical rules for solving problems. This can be achieved effectively if the students can decide their major upon entrance in a B.Sc. program. They already make such decisions when they enter engineering or medical colleges. However, this goal cannot be realized unless we make effective contact with the students both at the high school and the intermediate levels, by finding what really appeals to them. Our curriculum should also take into account the needs of less academically oriented.

A typical US graduate school[4] requires the following preparation before admission to graduate work:

(a) Mechanics (Symon: *Mechanics*; Marion: *Classical Dynamics*);
(b) Electricity (Reitz and Milford: *Foundations of Electromagnetism*; Marion: *Classical Electromagnetic Radiation*);
(c) Modern Physics (Eisberg: *Modern Physics*; Alonso and Finn: *University Physics*, Volume III);
(d) Heat and Statistical Mechanics (Zemansky: *Heat and Thermodynamics*; Rief: *Statistical and Thermal Physics*);
(e) Optics (Jenkins and White: *Optics*; Sears: *Optics*);
(f) Calculus (Kaplan: *Advanced Calculus*; Apostel: *Advanced Calculus*; Courant: *Differential and Integral Calculus*);
(g) Linear Algebra (Anton: *Elementary Linear Algebra*; Strong: *Linear Algebra and Its Applications*).

We need to cover this material in our undergraduate curriculum. Undergraduate courses must prepare the student to handle standard texts like Jackson: *Classical Electrodynamics*, Messiah: *Quantum Mechanics*, Goldstein: *Classical Mechanics*, and Killingbeck: *Applied Quantum Mechanics*. In addition, the student should know thoroughly Kittel and Kroemer: *Thermal Physics*.

In England, US and Canada the students have sixteen years of schooling before they get a B.Sc./B.S. degree. They spend three to four years in a bachelor's program. Then they spend one or two more years to get a master's degree. In Pakistan students study for only fourteen years to get a B.Sc. The bachelor's degree requires only two years (with an additional year for honors option). This is too short a period to properly educate them to enter a master's program. We are suggesting a three years B.S. program and another two years are to be spent to obtain an M.S.

In the following table a curriculum is proposed for physics majors. Upon entrance to a university the students have taken three years of physics, three years of chemistry and one year of calculus and analytic geometry. All courses are of three credit hours unless noted otherwise in parentheses after the course title. Superscripts a, b, c,... denote typical textbooks listed in Table IV. A list of possible options is included in Table V. A [C] in front of a course title denotes a core course.

The following abbreviations are used in the course listings.

PLI Physics Laboratory Instruction;
PRI Physics Recitation Instruction;
TOP Teaching of Physics, to be given jointly by the faculty of Physics and Education.

Methods of evaluation

In order to raise the standard of education, the notion that anyone who gets admitted to a university will end up with a degree should be abolished. The following measures are suggested to improve the situation.

(a) Those who fail more than two courses in a semester are automatically dismissed.
(b) Those who fail one or two courses may retake the examination during the 40 days grace-period.
(c) Those who have not cleared all courses after the grace-period are dismissed.
(d) Passing grade should be 50%. In core courses 60% or better must be scored.
(e) M.S. thesis should be defended before a committee with at least one external examiner.
(f) Written examinations in general physics[a] (superscripts suggest approximate level from the list given in Table IV), mechanics[d] and electromagnetism[e] must be passed to get an M.S. degree.
(g) Ph.D. Examinations: Written (described above); oral in modern physics[f], quantum mechanics[j] and statistical physics[h]; language (English and one other scientific language—German, French or Russian) and comprehensive oral (at least two members of the board should be from outside the department) examinations must be passed before a student is allowed to enroll for the third year.

Table 1 The B. S. Program

FIRST SEMESTER		SECOND SEMESTER
	First Year	
General Physics I[a] + Lab [C]		General Physics II[a] + Lab [C]
History and Philosophy of Physics[b]		Physical Basis of Astronomy[c]
Maths for Physicists I		Maths for Physicists II
Chemistry for Physicists I		Chemistry for Physicists II
English for Scientists I		English for Scientists II
Islamic and Pakistan Studies		Urdu for Scientists
	Second Year	
Mechanics I[d] + Lab [C]		Mechanics II[d] + Lab [C]
Electromagnetism I[e] + Lab [C]		Electromagnetism II[e] + Lab [C]
Modern Physics I[f] + Lab [C]		Modern Physics II[f] + Lab [C]
Scientific Writing[g] + TOP*		Thermal physics[h] [C]
Maths for Physicists III		Maths for Physicists IV
Statistics for Physicists I		Statistics for Physicists II
	Third Year	
Classical Mechanics[i] [C]		Relativity
Quantum Mechanics I[j] [C]		Quantum Mechanics II[j] [C]
Math Methods for Physicists I[k]		Math Methods for Physicists II[k]
Circuit Theory + Electronics[l]		Solid State Phys. + Cryogenics[m]
Nuclear and Particle Physics[n]		Optics + Spectroscopy[o]
Error Analysis[p] + Laboratory		Experiment Design[q] + Laboratory

*Student must write an essay and present it.

(h) During summer students could be assigned independent study, theoretical and experimental projects with accompanying written reports. Senior students could also work in industry and research institutes.

Teachers training and teaching aids

To handle such a demanding curriculum teachers need to be trained. Teachers should be prepared to teach all core courses; they should solve problems in class and maintain office hours to help students overcome their difficulties. This can be achieved through refresher and special courses for college and university teachers. Colloquia and seminars need to be organized by the universities and active participation in colloquia by college teachers should be encouraged.

Teaching load should be balanced so that a teacher can find time to do some research. For example, in Gomal University, Dera Ismail Khan, there are 18 teachers and 50 students in the Physics Department, while in Karachi University there are only 15 regular faculty members (2 of them are on study leave) in the Physics Department. The Department provides instruction for about 1300 students. There is a need of five more universities based on the population of Karachi.

To teach effectively there is a need to make avail-

Table 2 The M. S. Program

FIRST SEMESTER		SECOND SEMESTER
	First Year	
Electrodynamics I[r] [C]		Electrodynamics II[r] [C]
Advanced Quantum Mech. I[s] [C]		Advanced Quantum Mech. II[s] [C]
Computational Physics[t]		Statistical Mechanics[u] [C]
Applied Mathematics[v]		Advanced Laboratory
PLI I		PLI II
	Second Year	
Group Theory[w]		Optional II
Optional I		Optional III
Thesis (6)		Thesis (6)
Physics Seminar* + PRI I		Physics Seminar* + PRI II

*Student must write an essay and present it.

Table 3 The Ph.D. Program

FIRST SEMESTER		SECOND SEMESTER
	First Year	
Relativistic Quantum Mechanics[x]		Quantum Field Theory[x]
Optional		Radiative Processes[y]
Colloquium I (1)		Colloquium II (2)
Independent Study I (5)		Independent Study II (5)
PRI I		PRI II
	Second Year	
Quantum Kinetic Theory[z]		Optional
Colloquium III (1)		Colloquium III (1)
Research I (8)		Research II (8)
PRI III		PRI IV
	Third Year	
Research III (12)		Research IV (12)
PRI V		PRI VI

*Student gives a talk once during each semester.

able textbooks at cheaper prices. These textbooks should be supplemented with solution manuals for instructors and study guides for students as well as slides, films, charts, computers and journals.

Table 4 Typical textbooks

a	Resnick and Halliday: *Physics*
b	Asimov: *History of Physics*
c	Shu: *Physical Universe*
d	Marion: *Classical Dynamics*
e	Wangness: *Electromagnetic Fields*
f	Eisberg and Resnick: *Quantum Physics*
g	R. A. Day: *How to Write and Publish a Scientific Paper*, ISI Press, Philadelphia, Pa., 1979.
h	Kittel and Kroemer: *Thermal Physics*
i	Goldstein: *Classical Mechanics*
j	Cohen-Tannoudji, Diu and Laloe: *Quantum Mechanics*
k	Arfken: *Mathematical Methods*; Mathews and Walker: *Mathematical Methods*
l	Scoot: *Linear Circuits*; Malvino: *Transistor Circuit Approximation*
m	Rosenberg: *Solid State Physics*
n	Frauenfelder and Henley: *Subatomic Physics*
o	Thorne: *Spectrophysics*
p	Taylor: *Introduction to Error Analysis*
q	W. J. Diamond: *Practical Experiment Design for Engineer and Scientists*, Lifetime Learning Publications, Belmont, Ca., 1981.
r	Jackson: *Classical Electrodynamics*
s	Messiah: *Quantum Mechanics*
t	Kuo: *Computer Application of Numerical Methods*
u	Rief: *Statistical and Thermal Physics*
v	Killingbeck: *Applied Quantum Mechanics*
w	Hammermesh: *Group Theory*
x	Bjorken and Drell: *Relativistis Quantum Mechanics; Relativistis Quantum Fields*
y	Rybicki and Lightman: *Radiative Processes in Astrophysics*
z	Van de Groot et al: *Kinetic Theory*

An immediate task at hand is the revision of textbooks. Sixteen-year old textbooks are being taught in B.Sc. classes these days. There is also a need for adequate laboratory material, reference books and research journals all requiring large sum of money. It is a pity that Karachi University does not get Physical Review and Physical Review Letters and even Physics Abstracts.

Table 5 Optional courses

Optional courses could be selected from advanced courses offered in the following fields:

- Atomic and Molecular Physics, Spectroscopy and Laser Physics
- Nuclear Physics
- Solid State Physics, Electronics
- High Energy Physics, Astrophysics and Cosmology
- Condensed Matter Physics
- Mathematical Physics (topology, scattering theory, non-linear phenomena, relativity, field theory)
- Biophysics

Conclusions and recommendations

In Pakistan the brightest students compete for places in engineering and medical colleges. Those unable to find places in professional institutions come to the Physics Departments. In order to attract the very best to physics we need to make effective contact with prospective students by organizing open houses, summer programs for high school seniors, lectures in schools and colleges etc. Physics should be presented as fun through games and simulations, dramatic demonstrations, experiments/activities done outdoors and illustrations of physics in sports. Usefulness of physics can be demonstrated by daily life applications, interface of physics and technology and as a preparation of a scientific career. Students should also be educated in issues relating to physics and society, e.g. safety and risks of modern technology, pollution and disarmament as perceived by physicists. Introduction of fresh topics, e.g. nonlinear phenomena and chaos, electricity as carrier of information, statistical and macroscopic concept of entropy and physics of life could intrigue the minds of young students. Physics enrichment programs could be designed for talented students.

The fundamental responsibility of a physics teacher is to first enhance the teaching of basic theory, to execute closely such education of scientific methodology as induction, contrast, analogy and imitation, thought experiment and so on[5]. Students should be able to grasp the physics behind a mathematical equation[6].

To promote effective learning and teaching there should be continuous feedback from students—much more than the confidential evaluation form filled by each student at the end of a semester. The authors are trying, on their own, to change the format and style of the courses taught by them at KU where the instructor has more freedom to conduct a course. Such a freedom is not available in degree colleges. To illustrate the point we are including in appendices two sophomore level modern physics question papers set by the authors, one set by KAS for degree colleges and the other by SAK for KU. The course outline recommended by the University Grants Commission is the same for both programs.

There is a need for a regulating body which could maintain quality control over the choice of textbooks and journals published within the country. Such a body may be 'Pakistan Physics Society' which could publish one or a series of journals, e.g. Pakistan Journal of Physics instead of every university bringing out its own journal.

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APPENDIX A: QUESTION PAPER FOR LOCAL COLLEGES SET BY KAS

UNIVERSITY OF KARACHI
EXAMINATIONS DEPARTMENT

B.Sc. (PASS) SECOND YEAR
ANNUAL EXAMINATION 1987
PHYSICS PAPER-IV "MODERN PHYSICS"
Time Allowed: Three Hours; Max. Marks: 35

Instructions:
1. Answer Five questions in all, selecting at least two from each section.
2. Marks of parts are given in front of each.

SECTION A

1.(a) The energy density in Planck's law for blackbody radiation is given by

$$E(\mu) = [8Ah\nu^3/c^3]/[\exp(h\nu/kT) - 1]$$

Express the monochromatic energy density in terms of wavelength. 4

(b) What is the wavelength corresponding to the peak of blackbody radiation spectrum at 300K. Wein's constant is 2.998×10^{-3} mK. 3

2. (a) In Compton scattering calculate the maximum kinetic energy given to scattered electron for a given photon energy. 3

(b) If the work function of a metal is 2 eV, calculate the threshold wave length for photoelectric emission. With what velocity are the electrons emitted when the metal is irradiated with ultraviolet light of wavelength 4000 A°? Electron rest mass = 9.109×10^{-31} kg; Planck constant = 6.6256×10^{-34} Js. 4

3. (a) List the assumptions made in deriving the Bohr's theory. Discuss the deficiencies of the model. 3

[μ] Full text: https://www.ngds-ku.org/Papers/C24.pdf
[ν] Full text: https://www.ngds-ku.org/Papers/C28.pdf
[∀] Full text: https://www.ngds-ku.org/Papers/C25.pdf

(b) Find the ratio of the wavelength of the first lines in the various series of spectra for atomic hydrogen (Lyman, Balmer, Paschen, Brackett and Pfund series).

Rydberg constant = 1.0974×10^7 m^{-1}. 4

4. (a) State and explain the Heisenberg's uncertainty principle for position and momentum. 3

(b) What is the de Broglie wavelength of thermal neutrons at room temperature 27°C? The average kinetic energy of thermal neutrons produced in reactors is $(3/2)kT$ and mass of neutron is 1.67×10^{-27} kg. Boltzmann constant $k = 1.3805 \times 10^{-23}$ JK^{-1}. 4

5. (a) Establish the Schrodinger wave equation for a free particle moving along the y direction. 4

(b) Show that the operator $\delta/\delta x$ and x do not commute. 3

SECTION B

6. (a) Explain the terms mass deficit, binding energy and packing fraction. Discuss the connection between packing fraction and stability of a nucleus. 4

(b) Compute the total binding energy and binding fraction for a ^{238}U (92 protons and 146 neutrons). Mass of ^{238}U = 238.03 a.m.u.; mass of proton = 1.007277 a.m.u.; mass of neutron = 1.008665 a.m.u.; 1 a.m.u. = 1.6604×10^{-27} kg; velocity of light = 2.998×10^8 ms^{-1}. 3

7. (a) Show that the nucleus decays exponentially in time. 3

(b) The half life of ^{235}U is 7.13×10^8 years. What is the decay constant of ^{235}U and what is the probability that this nucleus will decay in one day? 4

8. (a) Discuss briefly the different types of nuclear reactions. 4

(b) Compute the Q value for the reaction: $^2H + {}^{63}Cu \longrightarrow n + {}^{64}Zn$. Atomic mass of ^2H = 2.014102 a.m.u.; atomic mass of ^{63}Cu = 62.929599 a.m.u.; atomic mass of n = 1.008665 a.m.u.; atomic mass of ^{64}Zn = 63.929145 a.m.u. 3

9. On the basis of band theory of solids, explain the electrical properties of conductors, semiconductors and insulators. 7

10. Write short notes on any two of the following: 7

(a) Fission, (b) Quadrupole Moment,
(c) Compound Nucleus, (d) Geiger-Muller counter.

APPENDIX B: QUESTION PAPER FOR PHYSICS DEPARTMENT, KU, SET BY SAK

DEPARTMENT OF PHYSICS, UNIVERSITY OF KARACHI

MAKE-UP EXAMINATION 402(H)
MODERN PHYSICS-I 1985–86
Max. Points 30; Time allowed 1.5 hr.;

Instructor S. A. Kamal

USEFUL INFORMATION: $m_\mu^+ = 209 m_e = m_\mu^-$; e (electron charge) = 1.602×10^{-19} C; $h = 6.626 \times 10^{-34}$ Js, $h/2\pi = 6.582 \times 10^{-22}$ MeV.s; $c = 2.998 \times 10^{10}$ cm.s^{-1}; 1 A° = 10^{-8} cm; energy of the electron in the nth orbit for hydrogen $E_n = -m_e e^4/(8h^2 n^2 \epsilon_0^2)$.

Note: Solve all the following. Each problem is worth six (6) points.

1. A photon of wavelength λ is Compton scattered at an angle ϕ. The wavelength of the scattered photon is λ_1. The shift in wavelength is given by $\lambda_1 - \lambda = (h/m_e c)(1 - \cos\phi)$. The quantity m_e is electron rest mass. In terms of photon energies this can be expressed as $\epsilon_1 = \epsilon/[1 + K(1 - cos\phi)]$. Find the value of K in terms of m_e, c and ϵ. If the recoiling electron gains a kinetic energy $m_e c^2$, the quantity $\lambda_1 + \lambda$ can be expressed as $(h/m_e c)(\cos^2\phi + m\cos\phi + n)^{1/2}$ where m and n are integers. Find the values of m and n.

2. The length contraction and time dilation are given by $dl' = dl(1 - \beta^2)^{1/2}$, $dt' = dt(1 - \beta^2)^{-1/2}$ where dl and dt are the length and time intervals in a frame (S), dl' and dt' are the values measured in a frame (S') moving with velocity βc. Dividing the first equation by the second and taking $dl/dt = c$, we get $dl'/dt' = (1 - \beta^2) dl/dt = c(1 - v^2/c^2)$. How can you explain the above equation when you know that the velocity of light is invariant in all frames of reference.

3. Find the ratio of wavelengths emitted for a $\mu^+\mu^-$ atom making transition from $n = 4$ to $n = 2$ to that for an e^+e^- atom making transition from $n = 5$ to $n = 4$.

4. Sodium light of wavelength 5890 A° enters glass having refractive index $n = 1.5$. In vacuum the proper mass of photon is zero. Because of interactions with the atoms in the glass plate the photon acquires an effective mass. Calculate its value in MeV/c^2. HINT: $E^2 = c^2p^2 + m_{eff}c^4$ and show that the momentum can be written as $p = (E/c^2)(c/n)$.

5. Obtain the relations between the Einstein coefficients by imagining the atom to be in thermal equilibrium with a neutrino field (spin $\frac{1}{2}$) rather than a photon field (spin 1). Neutrinos are Fermi-Dirac particles and obey the Pauli exclusion principle. In addition their equilibrium intensity is given by

$$I_\nu = [2h\nu^3/c^2]/[\exp(h\nu/kT) + 1].$$

The energy difference between level 2 and level 1 is $\Delta E = h\nu$. The number density and statistical weight of level 1 (level 2) are $n(n_2)$ and $g_1(g_2)$ respectively.

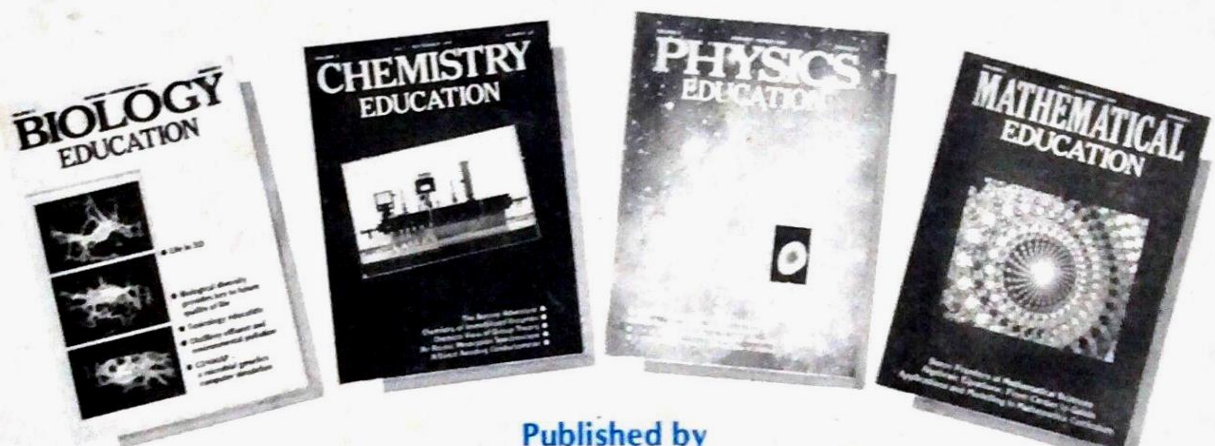
BONUS QUESTION (4 Points)

6. We know that $h = 6.67 \times 10^{-34}$ Js, $c = 3 \times 10^8 \text{ms}^{-1}$. In sixty (60) words or less describe what happens in each of the following situations:

(a) $h = 6.67 \times 10^{-34}$ Js, $c = 55$ mile/hr;

(b) $h = 100$ Js, $c = 3 \times 10^8$ ms^{-1};

(c) $h = 100$ Js, $c = 55$ mile/hr.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