I. INTRODUCTION

I am deeply honored to be the recipient of the Millikan Award for the year 2002. I see many of my colleagues and friends in the audience and would like to recognize them for all they have done to improve the teaching and learning of physics throughout the United States and the rest of the world.

I was born and raised in India where I received my education up to the Master’s level. I then taught for one year at a college and for two years in a university in India. My Ph.D. degree is from the University of British Columbia. In 1961 I became an assistant professor of physics at Long Beach State College in California. I would have stayed in Canada, but some of the faculty members there told me that the Americans had more money to set up an optics and spectroscopy teaching laboratory and a laboratory for my research projects. One of them told me that Long Beach was the place of the International Beauty Contest held every year! Then another faculty member chimed in to say, “That is why Simon wants to go to Long Beach.”

It was in Long Beach that I met and married my wife and true supporter Barbara and brought up our son Rajan.

In the following, I will discuss physics education in India and Malaysia, the Cambridge and Singapore Physics Examinations, and physics education in the United States.

II. PHYSICS EDUCATION IN INDIA

In receiving the AAPT Millikan award, I am reminded of the late Professor Harry Meiners who received this award about 30 years ago.1 As a staff scientist working for the National Science Foundation and the Agency for International Development, he spent three years in India working with the National Council for Research, Education and Training to help India improve physics education throughout the country.

I have tried to follow in his footsteps and collaborated with Professors Kumar and Khandelwal by doing a survey on “Science Education in India.” 2 In this article, we describe the education system in India with particular reference to teachers, curriculum, and examinations.

Before discussing this article, let me consider some statistical snapshots of education in India. The estimated population of India today is over one billion. The number of secondary schools is about 103,000. The total number of teachers in secondary schools is about 2.1 million, and the student enrollment is about 24 million. There are 229 universities and 9300 colleges with a total enrollment of about 5.4 million students. In 1997, the total number of students in K–12 was about 180 million compared with 45 million in the U.S.

India’s first prime minister, Nehru, once said: “It is science alone that can solve the problem of hunger and poverty. The future belongs to science and to those who make friends with science.” 3 Sir C. V. Raman, the Indian Nobel Laureate once said: “There is only one solution for India’s economic problems and that is science, and more science and still more science.” 4

To improve its educational policy, the Indian government set up an education commission in 1964 with Professor D. S. Kothari, a noted physicist and educator, as its chair. One of the aims of this commission was to devise a new structure for the Indian educational system that would be consistent with the values of freedom, social justice, and equal opportunity. The term “equal opportunity” is important in view of the social structure in India. Also, the National Council of Educational Research and Training (NCERT) was established as a permanent body to plan for improvements in education at the school level.

The NCERT has developed numerous educational aids and has helped considerably in extensive training and reorientation of teachers in all the Indian states. The educational pattern of the 10+2+3 year system was introduced around 1975 and many states in India have adopted this system. In this system, the first 10 years expose students to a broad overview of the different faculties of knowledge, including the sciences, arts, and the humanities. In the next two years or college level, students branch off to specific fields of interest such as science, the arts and languages, commerce, and agriculture. The final three years are at the university level, where the student can earn a B.S., B.A., or B.Com. degree (Bachelor of Commerce). The most significant aspect of the 10+2+3 system is that science and mathematics are taught up to the high school level to all students, both boys and girls, and urban and rural.

The instruction at the 10 level is usually in one of the 15 regional languages depending on the state and the school. At college +2 level, the medium of instruction is the regional language for about half the student population and in English for the other half, due to lack of good science textbooks in the regional languages. At the university +3 and postgraduate levels, science and all medical and engineering courses

Table I. Sample question from the IAPT exam (high school level).

In a Millikan oil drop experiment, one of the drops falls at speed $v$ without a field and rises at speed $2v$ with the field $E$ applied. If $E=V/2$, the drop will

a. fall with speed $v/4$.

b. rise with speed $v/2$.

c. rise with speed $3v/2$.

d. remain constant.

[DOI: 10.1119/1.1583697]
A satellite is in an orbit with radius $r$ and has an orbital velocity $v$. If $r$ is changed to $4r$, the new orbital velocity becomes

a. $\sqrt{2}v$

b. $v$

c. $2v$

d. $4v$

e. $16v$

are usually taught in the English language. Thus, proficiency in the English language continues to be a requirement for all students who desire to go on for higher studies in science and technology.

The Indian Association of Physics Teachers (IAPT) was established in 1984 mainly by the efforts of Dr. D. P. Kandavel, a true visionary who realized the importance of physics and physics teaching at the undergraduate level. Recently, one of the IAPT proposals called for overhauling the undergraduate physics laboratories, reorienting all undergraduate physics teachers in a period of two years, and establishing model undergraduate physics laboratories in the country. Many scientists in India have recognized that failure in science was due to the weak training at the undergraduate level.

In order to make comparisons of high school examinations, let me give your sample questions from the IAPT and AAPT regional test (California and Wyoming). These exams are comparable in quality as exemplified by the typical problems listed in Tables I–III.

II. IAPT SURVEY

In 1994 IAPT surveyed undergraduate physics courses at several universities in India. A report based on the random sampling of 20 universities is presented here. The relative time allocated to the teaching of theory varied from 50% to 60% of the total time available for the course. The rest of the time was available for teaching practical (experimental) physics. However, in terms of the points suggested for scoring the exam questions, the laboratory counts for no more than 15% to 50% of the total grade.

The questionnaire listed 8 pieces of equipment and asked if the laboratory in the 20 selected universities found them in working condition. The results are in Table IV.

The questionnaire also listed 9 types of measurements that might be required in the same universities (see Table V).

Note that the linear air-track had not reached any of the 20 universities. The He–Ne laser had reached only two institutions. But the amazing facts were that there was only one laboratory without a grating spectrometer, two without a cathode ray oscilloscope, and there were four institutions that did not have a photocell or an audio oscillator in their basic science lab. Such was the state of affairs in 1995.

The following quotes from two editorials, one in 1990 IAPT bulletin and the other in 2000, provide the latest evaluations of physics education in India today: “The style of examination needs alteration so that it is not characteristic of memory recall only. As a matter of fact, the reproduction of textual material may not be encouraged altogether in the examination. Rather the examination should lay emphasis on the application aspect and only problem/exercises should constitute the paper.” “The teaching community is not very clear about the importance of laboratory work. The administration in India particularly in the colleges and also to some extent in the universities underrate the laboratory work to a very large extent. At the employment level, the marks (points) awarded for the laboratory work, are very often totally ignored. The inflow of technological development into the students’ laboratory is very seriously delayed. It is not just a financial problem. There is a major component of management involved in it.”

III. PHYSICS EDUCATION IN MALAYSIA

The purpose of this section is to show that physics education has become important in Malaysia’s education system. It is also pointed out that in addition to the written examination, there is also a practical examination in which students are tested on the laboratory aspects of the physics course, very similar to examinations in schools in Great Britain and in most of the Commonwealth countries.

Malaysia, formerly Malaya, is in the central part of Southeast Asia and is slightly larger than New Mexico. It is a multi-racial country with a population of about 20 million. The density of population in Malaysia is roughly twice (125/ sq. mile) that of the U.S. The GNP per capita in Malaysia is

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Number of universities requiring this measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light intensity</td>
<td>9</td>
</tr>
<tr>
<td>Very low current</td>
<td>10</td>
</tr>
<tr>
<td>Very low resistance</td>
<td>13</td>
</tr>
<tr>
<td>Magnetic field of an electromagnet</td>
<td>9</td>
</tr>
<tr>
<td>LCR circuit resonance curve</td>
<td>16</td>
</tr>
<tr>
<td>Absorption spectrum of gas/liquid</td>
<td>5</td>
</tr>
<tr>
<td>Phase relation between $V_L$, $V_e$, $V_R$</td>
<td>9</td>
</tr>
<tr>
<td>Very low voltage</td>
<td>10</td>
</tr>
<tr>
<td>Very short time intervals</td>
<td>2</td>
</tr>
</tbody>
</table>
A force of 3.0N and a force of 4.0N act on an object at the same time. What is the acceleration of the sledge?

- a. 0.63
- b. 1.6
- c. 2.4
- d. 3.2

A sledge of mass 25 kg is pulled across level ground with a horizontal force of 60N. The constant force of friction is 20N. What is the acceleration of the sledge?

Table VII. Sample question from Singapore (O Level) examination.

1. A force of 3.0N and a force of 4.0N act on an object at the same time. Which of the following forces cannot be the resultant force on the object?

- a. 0.5N
- b. 3.5N
- c. 4.0N
- d. 5.0N

Table VIII. Sample question from Cambridge (A Level) examination.

1. What happens to the speed, frequency and wavelength of light when it enters glass from air:

<table>
<thead>
<tr>
<th>Speed</th>
<th>Frequency</th>
<th>Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Decreases</td>
<td>Increases</td>
</tr>
<tr>
<td>b.</td>
<td>Increases</td>
<td>Unchanged</td>
</tr>
<tr>
<td>c.</td>
<td>Unchanged</td>
<td>Decreases</td>
</tr>
<tr>
<td>d.</td>
<td>Decreases</td>
<td>Unchanged</td>
</tr>
</tbody>
</table>

Table IX. Sample question from Singapore (A Level) examination.

1. An electron beam enters a region in which there is an electric field perpendicular to the beam. A similar electron beam enters a magnetic field, also perpendicular to the beam direction. Does the magnitude of the force on the electrons depend on their speeds in these two fields?

<table>
<thead>
<tr>
<th>Electronic fields</th>
<th>Magnetic fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. no</td>
<td>no</td>
</tr>
<tr>
<td>b. no</td>
<td>yes</td>
</tr>
<tr>
<td>c. yes</td>
<td>no</td>
</tr>
<tr>
<td>d. yes</td>
<td>yes</td>
</tr>
</tbody>
</table>
Table X. Sample question from the SAT examination.

As compared with the nucleus of a lead atom with atomic mass 207, the nucleus of a lead atom with atomic mass 206 has:

a. One more proton
b. One less proton
c. One more neutron
d. One less neutron
e. One more electron

Table XI. Sample question from the AP physics examination.

An object is thrown with a horizontal velocity of 20 meters/sec from a cliff that is 125 m above level ground. If air resistance is negligible, the time it takes the object to fall to the ground from the cliff is most nearly:

a. 3 s
b. 5 s
c. 6 s
d. 12 s
e. 25 s

V. PHYSICS EDUCATION IN THE UNITED STATES

No other country in the world has put as much effort and resources into the teaching of physics as we have done. In order to compare the quality of precollege physics examination questions with those given in other countries, I would like to give a couple of examples. Table X gives a sample multiple-choice question in the SAT physics examination (precollege).

The Advanced Placement (AP) program consists of 32 college level courses and exams in 19 disciplines for highly motivated students in secondary schools. AP courses are offered in more than 11 700 high schools in the U.S. A sample multiple-choice question for Physics B (noncalculus) is in Table XI.

In my opinion physics education at the high school level is more than satisfactory in the U.S. compared with other countries I have visited. However, almost all the other countries require all students to have at least one course in physics before they graduate from high school. In the U.S. only 25 percent of the students at the high school level take physics. Bernie Khoury asks,11 “Does teaching physics require that we teach only 25 percent of the students at the high school level? Can we weaken the link between the way we have narrowly defined physics and the fact that a mere 25 percent of students choose to take our high school physics courses? A broader definition of physics and its appropriateness for all students would serve the interest of our society, our students and our discipline.” I could not agree with him more, but my main concern is with the K–8 physical science courses in the United States. A good number of the teachers do not have the proper background in physical science. Bear in mind that K–8 students are eager to learn exciting things in science and for that we need well-prepared teachers.

I will give a couple of comments from my students (K–8 teachers) who attended the physical science workshops conducted at California State University, Long Beach. The following comments are from two fifth grade elementary school teachers, one with 16 years of teaching experience and the other with 20 years of teaching experience. “Frankly, I have felt inept and fearful about presenting science in an interesting manner to my students. I have avoided teaching science in the past.

In fact, I’ve bribed other teachers to teach science for me in exchange for my ability to teach social studies, art, music, or physical education to their students... my experience in your class has reminded me that science can be fun. You’ve used proven teaching strategies by backing up your theories with concrete examples and experiments.” "Since I know so little about science, I do not feel comfortable teaching it. With this workshop, I plan to gain more knowledge about science and thus increase my confidence in teaching it.”

Bernie Khoury says that “We should ask ourselves why such a large percentage of teachers in the K–8 levels are not comfortable in teaching science to their students. These teachers have been graduated from our own colleges and universities, often after being totally ignored by the science faculty. We should keep in mind that virtually all K–8 teachers are science teachers. These are the teachers from whom students learn long-lasting lessons about science. Discouragement and disinterest instilled in those early grades are difficult to overcome; many students never recover from those early perceptions that they infer from teachers.”12 Let us not overlook this serious problem. I call on AAPT (both national and regional) to increase their efforts in helping K–8 teachers to achieve more confidence in teaching science.

Len Jossem has remarked that “Increased ease of communication makes it easier for mutual support across boundaries. As never before, we can help each other in the development and application of new ideas and methods.”13 As U.S. educators, let us try to help teachers in other countries improve the laboratory education in physics. I believe we can play a significant role in collaborative efforts that will prove to be mutually beneficial.

ACKNOWLEDGMENTS

I want to dedicate this award to my teachers and to my students. Without them, I would not be standing here today. It is a pleasure to acknowledge the invaluable help of my friend and colleague, Herbert H. Gottlieb, in the preparation and editing of this paper.
the exam was a trial because of the practice of letting the students take the
exam booklet back to their teachers so that a brand new exam was needed
each year. During the 1960s the exam was administered by Derek Prowse
(who took the exam with him when he transferred to the University of
Wyoming). Derek died in a snowmobile disaster in 1970, whereupon
Lester Hirsch and Walter Ogier took on the exam and ran it for many years
for the benefit of high school physics students in California and Wyoming.
The exam sputtered out in 1992 when the national AAPT began their
program of exams preliminary to the Physics Olympics. Walter Ogier,
private communication.

8T. R. Anantha Krishnan, “Survey regarding undergraduate physics courses
in different universities in India,” Bull. Indian Assoc. Phys. Teachers 12
(4), 100 (1990).
10Babulal Saraf, “The role of laboratory in physics education,” Bull. Indian
11Bernard V. Khoury, “Whom do we teach? What do we teach?,” AAPT
12Bernard V. Khoury, “The preparation and professional development of
13Leonard Jossem, VII Inter-American Conference on Physics Education,