A Career as a Physicist

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1 Introduction

A career decision influences greatly what a student shall work on for about thirty years of her or his life. Therefore it is important for a student to consider not just the salary prospects of a particular career but also her or his interests and talents while choosing a career. Here we discuss the path one must follow if a student has an interest in the area of Physics and wishes to consider a career as a physicist. We also mention current salaries and job prospects in this field. [1]

By a physicist we refer to a scientist who is active in doing research in any branch of Physics, such as Solid State Physics, Particle Physics, Plasma Physics, Lasers, Atmospheric Physics, Space Sciences, etc. Carrying out research is very different from learning about a subject in college. In the latter case one is learning about issues that are already well understood and are solving problems for which solutions exist (even if they may seem intractable to the student). However the goal of a research scientist is to explain phenomena that are not yet understood or to propose experiments

[1] This essay was largely written in 2006 and some of the information in this essay may need to be updated.

that can give us a fresh and better understanding of nature. This is generally very challenging even though a scientist makes use of the knowledge and ideas that have preceded her or him. In most professions, one generally can satisfy one's responsibilities by using what one has learned. For example, most of the cases that a doctor treats involves diseases that a doctor has studied about and treated before. Only a small percentage of her or his cases will involve ailments that are completely new and for which no treatment yet exists. But now imagine if you were a doctor whose every case involves ailments that are not yet well understood and for which you need to find cures. This would be analogous to the life of a research scientist or a physicist. A researcher's domain is not that of the known but of the unknown.

Part of the challenge for a physicist is that there are times when despite one's best efforts a problem will remain unsolved. On the other hand, a physicist's reward is the sense of satisfaction that one feels when one is successful in explaining a phenomena that was previously not understood and in adding to the shared body of knowledge of all humankind.

Most scientific research has some direct or indirect technological impact in the long run. Therefore society funds research in science because scientific discoveries fuel humankind's technological advancement. In India research in Physics is carried out on a major scale at various research institutes, government-funded applied research organisations and at some universities. Currently there are only a few industrial research centres in India. Research in Physics abroad, particularly in the US, is carried out primarily at universities and also at some research institutions and industrial research centres. Typically a career as a physicist in India or abroad requires one to obtain a Ph.D. in Physics. Therefore a student who is considering a career as a physicist must obtain a B.Sc., an M.Sc and then a Ph.D. in Physics.

2 B.Sc. Programme

• Where to register for B.Sc.?

In India: Many institutions in India provide a reasonably good course in Physics. The Integrated B.Sc.-M.Sc. programmes at IIT Kanpur, Kharagpur and Madras, and Engineering Phyiscs at IIT Bombay, Delhi and Madras

are particularly good. The Chennai Mathematical Institute in Chennai also offers a good B.Sc. degree in Physics. In addition, in 2006 Integrated B.Sc.-M.Sc. programmes were introduced at the University of Hyderabad and at the newly-established Indian Institutes for Science Education and Research (IISER) at Pune and Calcutta. IISERs have since been established at Chandigarh, Bhopal and Trivandrum. Integrated B.Sc.-M.Sc. programmes have commenced at the Centre for Excellence in Basic Sciences of the University of Mumbai and the Department of Atomic Energy, and at the National Institute of Science Education and Research (NISER) at Bhubaneswar. BITS, Pilani offers a dual B.Tech/M.Sc. programme. Pondicherry University also offers an Integrated B.Sc.-M.Sc. Programme. In 2011, the Indian Institute of Science at Bangalore has initiated a 4-year B.S. in Physics.

In USA: There are some colleges in the US that give scholarships for foreign students for the Bachelor's degree. Admission to US colleges is based on an application, school marks, teachers' recommendations and performance on standardised tests like SAT, ACT and TOEFL. A student can get more information about these tests from the US Educational Foundations in India or websites of various universities.

• What should I read during the B.Sc.?

In addition to the texts prescribed as part of the college curriculum it is imperative for the student to expand her or his knowledge by referring to some other texts. We give in the Appendices a list of some texts that a student can choose from and we strongly urge the student to solve the problems in these books.

Besides solving problems in Physics, it is important for the student to acquire proficiency in English, both spoken and written. English is the language of science and is used by scientists across the world to share their results. Furthermore, many good books are available only in English.

• How does a student get exposed to the research community during his B.Sc.?

Students pursuing a Bachelor's degree in Physics in India rarely get to meet physicists who are actively conducting research. Therefore it is in the in-

terest of the student to contact scientists at institutions where research is carried out and to explore the possibility of working on projects with them either during the academic year or during vacations. These projects will give students an insight into the world of scientific research and allow them to ascertain for themselves whether or not a scientific career appeals to them. Some institutions such as the Tata Institute of Fundamental Research at Bombay, the Saha Institute of Nuclear Physics at Calcutta, the Institute of Mathematical Sciences at Chennai and JNCASR at Bangalore do have formal programmes during vacations for B.Sc. students. However even if an institution does not have a formal programme individual scientists may be willing to work with young students. Students selected under the Kishore Vaigyanik Protsahan Yojana (KVPY) also get an opportunity to do research at various institutions in India. The Homi Bhabha Centre for Science Education organises summer programmes for B.Sc. students under the National Initiative on Undergraduate Science. Some of the summer programmes for M.Sc. students mentioned below also admit B.Sc. students.

3 M.Sc. Programme

• Where to register for M.Sc.?

Experimental facilities and computer facilities are very vital for the M.Sc. programme. A list of institutions in India which provide good M.Sc. programmes is available at http://www.sayantanghosh.50megs.com .

• What should I read?

A list of books that may be read during the M.Sc. is provided in the Appendices.

• Can I involve myself in a scientific project during my M.Sc.?

During the M.Sc. the student should also try to work on projects. Besides exploring the possibility of working informally with scientists as mentioned above the student should also apply to participate in formal programmes at institutions such as the Physical Research Laboratory at Ahmedabad, the

Inter-University Centre for Astronomy and Astrophysics at Pune, etc. where she or he can work on a project in the summer vacation between the first and second years of the M.Sc. At http://www.sayantanghosh.50megs.com we list such programmes for M.Sc. students at various institutions in India. Note that any projects done during the B.Sc or M.Sc. may be relevant if one wishes to apply to a Ph.D. programme abroad or in India.

4 Ph.D. Programme

If a student is still keen on a career as a physicist after an M.Sc. then she or he may apply to join a Ph.D. programme. This is a new phase in a student's career- rather than the traditional mode of learning in classrooms the student will now learn by conducting research under the supervision of a guide. Obtaining a Ph.D. takes about 5 years and requires the student to obtain some new results in the chosen area of research.

At this stage there are two options. The student may opt to do a Ph.D. in India or abroad. There are good scientists in India, just as abroad, with whom one can work for a Ph.D. Furthermore many of the premier institutions in India do have good library and internet facilities. However, the facilities available for research in experimental physics at Indian institutions may sometimes be inadequate. Another advantage of doing a Ph.D. abroad, particularly in the US, is that there are many more institutions in countries like the US where research is carried out. Therefore a student gets exposure to a larger number of scientists through conferences and through visits by scientists for giving seminars at the student's university.

• Admissions to Ph.D. programmes in India

To register for a Ph.D. with the post-graduate department of any university in India the student should write to the registrar of the university to obtain information about procedures and deadlines. To join the Ph.D. programme at one of the several research institutes in India one typically has to appear for a written test and subsequently an interview. The website http://www.sayantanghosh.50megs.com lists some good institutions in India where one may obtain a Ph.D. The student should write directly to the institutions, or check their websites on the internet, to obtain further details.

Ph.D. students at universities in India are usually not paid a stipend by the university but may receive a stipend from the research grant of their Ph.D. supervisor. They are eligible for UGC/CSIR NET fellowships. Ph.D. students at research institutes are paid a stipend. In 2007, the typical NET fellowship or institute stipend varies between of Rs. 8000/- to Rs 10,000/- per month depending on the institution and the seniority of the student.

• Admissions to Ph.D. programmes in the US

Admissions to Ph.D. programmes in the US are based on the following criteria:

1. marks obtained at the B.Sc. and M.Sc.
2. marks obtained in the GRE (Graduate Record Examination) and the Advanced or Subject GRE exams conducted in India by the Educational Testing Service (ETS) of the US
3. three letters of recommendation by B.Sc or M.Sc. teachers
4. an essay on why you wish to do a Ph.D. in Physics
5. any research projects the student may have worked on

The above criteria are the same for both American and non-American students. Non-native speakers of English are also required to take an additional test called TOEFL (Test of English as a Foreign Language). There are some websites that provide practice tests for the GRE. ETS also provides a sample GRE Physics Test Practice Book.

The academic year in the US starts in August or September. Typically the student should take the GRE exams by December of the year prior to the planned year of admission. Application forms for the Ph.D. programme are available directly from the website of the Physics Department that the student wishes to apply to. The completed forms are due by December or January. The student is required to send only those marks that are available. So, for example, if the student applies during her or his IInd year of M.Sc. she or he will only have to send marks of the Ist year of M.Sc. (and of the first semester of the IInd year of M.Sc., if available). A student should contact

universities in August or September of the year prior to the year in which he or she plans to join the Ph.D. programme.

The Bachelor's programme in the US is 4 years long. It is rare for universities in the US to grant Master's degrees in Physics and a student directly joins the Ph.D. programme after a Bachelor's degree. Since a student enters the Ph.D. programme in the US after 16 years of education, an Indian student may join a US Ph.D. programme after completing either both years or just the first year of the M.Sc. in India. Some universities in the US may admit Indian students after a B.Sc. However since the 4-year US Bachelor's programme is more rigourous than the 3-year Indian one, and the coursework during the Ph.D. is also demanding, we recommend that Indian students complete their M.Sc. in India before joining a Ph.D. programme in the US. A student may also be better prepared to take the GRE examination in Physics after the first year of the M.Sc. Note that US universities in some cases do consider applications for a Ph.D. in Physics from those whose Bachelor's degree is not in Physics, but in other disciplines such as Engineering or Mathematics.

Most students in a Ph.D. programme in Physics in the US are paid a stipend that is sufficient to cover tuition and living expenses. The website http://www.sayantanghosh.50megs.com gives a listing of some good US universities and their application fees (in 2006).

5 After Ph.D.

After completing a Ph.D. in Physics one may obtain a position that involves either only teaching or only research or both teaching and research. In India, a teaching position at a college or at a university does not require one to do research. However some universities do have strong research programmes. Research grants are available from the Dept. of Science and Technology, the University Grants Commission, etc. Research institutes such as PRL, TIFR, etc. are primarily research institutions and the teaching load is minimal. Government-funded applied research organisations such as CSIR laboratories, BARC and ISRO are purely research centres with no teaching. The IIT's do emphasise both research and teaching. Currently there are few industrial research positions in India. In the US, after a Ph.D. one may either teach at a college where research is not emphasised or teach at a university

where research is a requirement or work for a governmental or industrial research laboratory. In both India and the US, one typically has greater freedom to choose the topic of research at a university or a research institute than at an applied research centre or at a governmental or industrial laboratory. (Note that, both in India and in the US, some of the positions involving research may require the candidate to have carried out 2-4 years of research subsequent to completion of the Ph.D. through temporary research positions referred to as post-doctoral fellowships.)

It must be clear that a Ph.D. in Physics does not guarantee a job in Physics either in India or in the US. Many physicists have had to look for employment in other areas such as finance, information technology, etc. despite having completed a Ph.D. and having carried out good research in their areas of research. Often the skills acquired in Physics, such as programming and solving complex problems, are of use in these jobs.

Typical salaries for a physicist, in India or abroad, are generally comfortable but are not amongst the highest in society. This should be offset against the opportunity to do what one enjoys doing. Salaries in academia have increased considerably since 2009 after the implementation of the recommendations of the 6th Pay Commission and other similar commissions. The salary for positions in colleges and universities, Indian research institutes and government labs (in 2011) varies from from approximately Rs. 36,000 per month to Rs. 1,30,000 per month depending on the institution and seniority. Please note that these are indicative of salaries in 2011 and the salary structure in the future may not be similar to the above. Salaries are typically higher at the few industrial reseach centres.

A career as a physicist is not a traditional choice in India today. Therefore a student may not be aware of many people who can guide her or him. So a student should not hesitate to contact those in the field of research for information or assistance. Most will be glad to talk or meet with the student but the student will have to make the effort to approach them. Also a student should not hesitate to consider a Ph.D. either in India or abroad just because no classmates or seniors of the student are considering it. Many students from all over India have opted for a career in Physics. Of course one's success will be a function of one's talents.

Appendices

Below we present some books that a student can read during the B.Sc. and M.Sc. The lists of books are not exhaustive and students should also consider other books that are available. Keep in mind that solving problems from these books is essential.

Note that many books are now available in low-priced Indian editions.

A. Books to read during B.Sc.

1. Fundamentals of Physics by David Halliday, Robert Resnick and Jearl Walker
2. Mechanics by Keith R. Symon
3. Introduction to Electrodynamics by David J. Griffiths
4. Classical Electricity and Magnetism by W.K.H. Panofsky and M. Philips
5. A Textbook of Quantum Mechanics, P.M. Mathews and Venkatesan
6. Quantum Mechanics: Theory and Applications by Ajoy Ghatak and S. Lokanathan
7. Introduction to Quantum Mechanics by David J. Griffiths
8. Introductory Quantum Mechanics by Richard Liboff
9. Quantum Physics by Stephen Gasiorowicz
10. Mathematical Methods in the Physical Sciences by Mary L. Boas

B. Books to read during M.Sc.

1. Classical Mechanics by H. Goldstein
2. Classical Electrodynamics by J. D. Jackson
3. Principles of Quantum Mechanics by R. Shankar
4. Modern Quantum Mechanics by J.J. Sakurai

5. Fundamentals of Statistical and Thermal Physics by Frederick Reif

6. Mathematical Methods for Physicists by George B. Arfken and Hans J. Weber

7. Complex Variables and Applications by R. V. Churchill and J. W. Brown