*IOSR Journal of Applied Physics (IOSR-JAP)*
*e-ISSN: 2278-4861.Volume 8, Issue 1 Ver. I (Jan. - Feb. 2016), PP 07-10*
*www.iosrjournals*

# Surveying Students` Misconceptions and Understanding in Nuclear Physics

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***Abstract:*** *In recent years physics education research (PER) has gained lot of prominence in effective delivery and understanding of physics learning. Understanding students' prior belief in nuclear physics is a first step towards improving nuclear physics instructions. Hence development of research-based multiple-choice questions tests about Nuclear Physics is important for assessing student's difficulties and for evaluating curriculum and pedagogies to reduce the difficulties. Nuclear Physics is taught at the bachelor degree B.Sc. programme and master degree M.Sc. level in all the colleges and universities of Himachal Pradesh. We explore the difficulties that the undergraduate B.Sc. and postgraduate M.Sc. students have with nuclear physics. We developed research-based conceptual multiple-choice questions survey that targets these issues to obtain information about the common difficulties and administered it to 101 students from five different institutions. The issues targeted in the survey include the Radioactivity, decay law, half life, Binding energy, nuclear forces and nuclear dimensions. We find that the students have many common difficulties with the concept of radioactivity, half life, nuclear forces and binding energy. Research based tutorials and peer-instruction tools will be used to reduce these difficulties in future studies and the survey will be again administered to assess the effectiveness of various instructional strategies.*

***Keywords:*** *Nuclear physics, multiple–choice survey*

## I. Introduction

Physics Education Research (PER) has become recognized as a legitimate research subfield of physics and recently emerged as new field of research in physics departments and physicists have begun to treat the teaching and learning of physics as a research problem similar to any applied science. It is based on the learning theory with the aim of introducing well defined learning outcomes / objectives for approving methodology of teaching and learning assessment. Today education is treated as topic worthy of scientific study. It is well known that pre-existing knowledge and beliefs can strongly influence how new concepts are understood [1]. Learning nuclear physics is challenging. A good understanding of Nuclear Physics requires mathematics and knowledge structure of quantum mechanics. Research-based conceptual multiple choice surveys are useful tools for evaluating students' understanding of various topics [2].The multiple choice surveys are easy to administer and grade. Their scores are objective and amenable to the statistical analysis. The force concept inventory (FCI) is a conceptual multiple choice tests [3] that helped many instructors recognize that many introductory physics students were not developing a functional understanding of concepts although they performed reasonably well on quantitative problems. Other conceptual surveys have also been designed for many physics topics, e.g., electricity and magnetism [4, 5]. These surveys reveal that students have many common conceptual difficulties with different topics in classical physics. Research-based instructional strategies have been shown to improve Students' conceptual understanding of some of these topics significantly [5].

The conceptual difficulties that students have in the undergraduate and post graduate courses are manifested even within the lower classes (10+2) introductory chapters of nuclear physics. We developed the nuclear physics survey which is 15-items multiple choice test covering various topics i.e. radioactivity, decay law binding energy and nuclear forces, nuclear dimensions The survey was developed by consulting with many nuclear physics instructors who are teaching nuclear physics course from more than 15 years in the u/g colleges affiliated with Himachal Pradesh University Shimla-5 (Summer Hill) and p/g level in the universities (Central University of H.P.). To investigate students' difficulties with various concepts, we administered free response and multiple choice questions and conducted interviews with individual students. Individual interviews with the students during the investigation of the difficulties and the development of the survey were useful to obtain an in depth understanding of students thought processes.

## II. Survey Design

The Nuclear Physics Survey (NPS) focuses on assessing students' understanding of the conceptual framework of nuclear physics instead of assessing their mathematical skill. We analyzed and evaluated the syllabi of Nuclear Physics taught in the colleges major core course VIII (NUCLEAR PHYSICS code BSCPHY0408) of Himachal Pradesh University Shimla-Summer Hill and Central University of H.P. Dharamshala at shahpur (NUCLEAR AND PARTICLE PHYSICS code PAS 409). Then common important concepts at u/g and p/g level were selected after taking opinion of the instructors (subject experts) we paid particular attention to the issue of reliability and validity [6-8] while designing the NPS. Reliability refers to the relative degree of consistency between the test scores if an individual repeats the test procedures. Validity refers to the appropriateness of interpreting the test scores. To ensure that the survey is valid, the opinions of several instructors about goals of course and the concepts and skills their students have learned were taken in to account. We sent e-mails to instructors in the colleges and universities to get their opinions and suggestions and finally we received e mails with their suggestions, comments and opinions. Apart from asking the instructors about these issues through emails, we discussed these issues individually with several instructors at Central University of H.P. Dharamshala Kangra (H.P.) and colleges in the district Kangra of Himachal Pradesh, i.e. Govt. P. G. College Palampur and Dharamshala. The NPS (Nuclear Physics Survey) includes a wide range of topics that the instructors expected their students to know such as the Radioactivity, Decay law, half life, Nuclear forces, Binding energy and Nuclear Dimensions. In developing good alternative choices for the multiple-choice questions, we took advantage of the prior investigations of advanced students' difficulties with various topics at the undergraduate level e.g., Binding energy and Decay law. The alternative choices for each question often had distracters (incorrect choices) which reflected students 'common misconceptions [9] to increase the discriminating properties of the questions. Having good distractors (incorrect choices) in the alternative choices is important so that the students do not select the correct answer for the wrong reason. To investigate students' difficulties further with some concepts before designing the multiple choice questions for the NPS, we developed and administered open-ended (or free-response) questions to the students. The answers to the open-ended questions were summarized and categorized and helped in develop good alternative choices for MCQ of NPS.

**Question 1**

For a radioactive nuclei obeying radioactive decay law $N = N_o e^{-\lambda t}$ and at half life ($T_{1/2}$), $N = N_0/2$ consider a radioactive sample with initially 1000 atoms. How many half-lives have elapsed when 750 atoms have decayed?

A) 0.25 B) 0.41 C) 0.50 D) 0.75 E) 1.3 F) 2.0

G) 2.4 H) 4.0

Question 1 tests the conceptual understanding of the radioactive decay law. The correct answer is two half-lives. It is however simpler to successively use the definition of a half-life: since only one quarter of the original nuclei have remained, two half-lives must have elapsed. It is noticeable that, of those students with the correct answer, the great majority argued with the definition of the half-life and did not use the formula, whereas for students with the incorrect answer, a much greater percentage of students used the decay law formula to calculate half life and chosen wrong option. Incorrect answers were 0.41 (ten postgraduate students and twenty five in the under-graduate) and 0.50 (five students in the post-graduate) This result can be obtained by calculation using the decay law $N(t) = N0 \exp(-\lambda t) = N02-t/T1/2$ , where $\lambda$ is the decay constant and $T1/2$ is the half-life.

**Question 2**

Half life ($T_{1/2}$) of radioactive nuclide is expressed as $T_{1/2}=0.693/\lambda$ and at $T_{1/2}$ $N=N_0/2$ considers a radioactive sample containing only a single type of radioactive nuclide that decays to a stable daughter nucleus. What fraction of radioactive nuclei remains after 4 (four) half-lives?

A) 1/2 B) 1/4 C) 1/8
D) 1/16 E) 1/32 F) 1/64

**Question 5**:- Which of the four known forces of nature is responsible for gamma γ decay?
A) Strong force B) Weak force C) Electromagnetic force D) Gravitational
**Question 8**:- Nuclear radius (R) is expressed in terms of mass number (A) as $R=R_oA^{1/3}$, How does nuclear mass density change with increasing mass number?
A) it increases exponentially

B) it increases linearly
C) it remains constant to a good approximation.
D) it decreases linearly
E) it decreases exponentially

In Question 5 and 8 90% students marked correct answer with reasoning option certain and 20% students marked with correct answer E of question2.

## III. The Survey Results

The NPS was administered to 101 students from 5 institutions (3 different classes were involved at post graduate level and undergraduate level). Among the 101 students, 51 were IVth semester undergraduate college students enrolled B.Sc.(Major Physics) at Govt. P.G college Chamba (H.P.) and D.A.V. College Banikhet (Dalhousie ) and 50 students enrolled for M.Sc.(Physics) of Sai University -Palampur, MCM-DAV college Kangra and central university of Himachal Pradesh shahpur

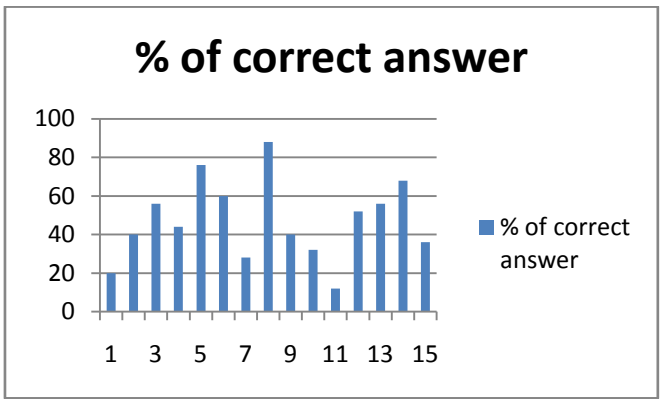


Figure 1: correct response outcome of the survey of post graduate students.

Survey result of the test given by the M.Sc. (Physics) students of Sai University Palampur and DAV College Kangra conducted at Central University of Himachal Pradesh at Shahpur. It is clear from the result that no one has given correct response of Q.No.1 (misconception about half life of radioactive element) while 32% of students responds correct answer for Q.No2
FIG. 1: A view of the students attempting nuclear physics survey at central university of Himachal Pradesh.

## IV. Item Analysis

| **Concepts** | **Number** |
|---|---|
| Half life of radioactive element | 2 |
| Binding energy | 3 |
| α ,β , γ, Decay | 5 |
| Nuclear dimensions | 3 |
| Nuclear density and shape | 2 |

**Table 1** number of questions belonging to each category

We diagnose and found that students have common difficulties (misconceptions) about radioactive decay law. Half life, Binding energy and $\beta^-$ decay and electron capture.

In future, we plan to administer the revised survey to a greater number of students, and aim to use survey in the colleges functioning in the most educationally backward regions of district Chamba (H.P.) to determine response for diverse student populations. We aim to conduct student interviews to gain more insight in to student thinking.

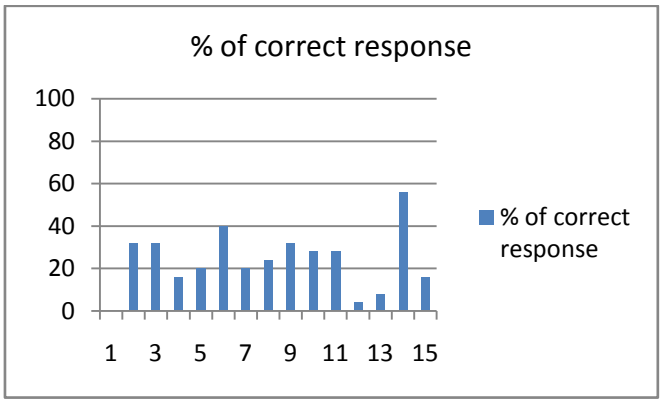


Figure 2: correct response outcome of the survey of undergraduate students

## Acknowledgements

The authors thank all those who helped him in this work specially Associate Professor of Physics at Govt. P.G. College Palampur, Dharamshala and DAV College Banikhet for helping him in conducting the survey.

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