Pre-labs as Advance Organizers to Facilitate Meaningful Learning in the Physical Science Laboratory

Dr. Muhammad Safdar

Vice Principal, Islamabad Model College for Boys G-6/2, Islamabad (Pakistan). safdarpkpk@yahoo.com

Dr. Iqbal Shah

Assistant Professor, Science Education Department, Allama Iqbal Open University, Islamabad.

Dr. Qudsia Rifat, Ex. Chairperson

Science Education Department, Allama Iqbal Open University, Islamabad.

Dr. Tanvir Afzal

Lecturer Secondary Teacher Education Department

Allama Iqbal

Open University, Islamabad.

Riaz Hussain Malik

Assistant Educational Advisor

Curriculum Wing

Ministry of CA&D, Islamabad

Abstract

This paper describes a tool (pre-lab as an advance organizer) which is used to find out the effect of pre laboratory activities on the learning of the students at secondary school level. Twenty experiments from the secondary school physics curriculum were selected; the pre-labs and post-labs are then developed keeping in view the levels of Bloom's Taxonomy. The psychological foundation underlying this tool is presented briefly. The issues of the without pre-laboratory work and rote-mode nature of learning in many countries of the world like Pakistan, and the importance of prior knowledge which is prerequisite for meaningful learning is discussed. There was a good sign of improvement in the achievement of the students having pre-labs as advance organizers. The findings of this research study and the data available to date from many qualitative and quantitative studies strongly support the pre-laboratories activities for cognitive gain. The paper emphasizes that the pre-lab activities should be introduced in the secondary school science laboratories specifically at physics.

Key words

Pre-lab, advance organizer, meaningful learning

Introduction

In science education we are teaching students to use one form of knowing that is the experimental. Effective classroom teaching in science requires advance thinking and proper planning. Certain points like objectives, content, methods, teaching aids, evaluation techniques are required to be attended to properly in advance for achieving desired outcomes. At secondary level, science education provides the students with opportunities to think critically, practice different teaching methods and develop scientific concepts, which facilitate the understanding of the physical environment.

No course in science can be considered as complete without including some practical work in it. The practical work is to be carried out by individuals in a physical science laboratory. At school stage practical work is more important because of the fact that we "learn by doing" scientific principles and applications are thus render more meaningful. It is well-known fact that an object handled impresses itself more firmly on the mind than an object merely seen from a distance.

Practical work forms a prominent feature in any science course. Amit Kumar, (1995), states that class room experiments help in broadening pupil's experience and develop initiative, resourcefulness and cooperation. Mostly, the activities performed by the students in the physical science laboratories at secondary level are; Verification activities, Exploratory Activities, Inductive Activities, Deductive Activities, Problem-Solving Activities, and Psycho-Motor skill development Activities.

Pre-lab activities as Advance Organizers

Expecting students to engage in laboratory activities without some form of prior consideration may leave them feeling insecure, and result in a rather poor understanding of what is happening. It is therefore useful to engage them in some form of pre-lab activity highlighting the essential ideas of the work. Bond, David Jeffery, et.al. (1986), describe that pre-lab activity may be conducted in the first portion of the laboratory time, or carried out prior to the scheduled laboratory period. It provides laboratory students to reflect on what has happened, and to check up on any aspects of information that they are unsure about. Another approach, which has been used for many years in one of the author's courses on analytical chemistry, is in the form of written assignment. The students involved in the practicals are to require questions on the activity to be answered by them in a written assignment before they enter the laboratory. The purpose of the questions is:

(i) To ensure that the students know, in general terms, what will happen in the next laboratory session?

(ii) To assist students to understand the steps involved in the analytical procedure by focusing attention on the chemical / physical processes involved.

(iii) To direct student's attention to key aspects of the procedure.

Some of the answers to the questions can be derived from information provided in the manual but the use of textbooks / notebooks are also required. Students are expected to arrive at the laboratory session with written answers, which are inspected and checked by staff. Those who arrive with no pre-laboratory write-up are not allowed to carry out the activity. Students respond very well to the idea of preparedness for laboratory work and once the system has been established for a week or two it runs very smoothly.

Another method discussed by bond, (1986), for the exposure of students to laboratory activities both prior to and during the laboratory session is through the use of media such as videotapes and tape-slide program. These are popular because the products are cheap to prepare and can be easily changed or edited to suit any particular teacher or class. The uses of media have several advantages: (a) Material can be placed in libraries or other readily accessible places. (b) All students receive the same information. (c) The material can also be placed in the laboratory, during the session for re-view by students who need reinforcement. (d) Specific procedures or techniques can be displayed in a manner not readily available in other formats i.e. close ups of small-scale techniques which may be difficult to demonstrate to large groups of students in the laboratory.

Computer assisted learning (CAL) is increasingly used in a pre-laboratory role, as a means of guiding the student through the theory associated with an experiment, and examining the experimental design. A good example of the use of CAL in the pre-laboratory mode has been provided by Bond, Jeffery and Elizabeth, (1986), whose physics laboratory students complete a CAL activity prior to the actual experiment. The program provided a general description of the experiment; the student then selected the independent variable and assigned values to them. The simulation provided data on the dependent variables just as would be provided in the laboratory. All of these different experiences can give the student mental or physical practice for the coming experiment, and maximize the efficient use of laboratory time.

Bond (1986), reported ten laboratory lessons for an organic laboratory course, and claimed that in nine of them the use of the programs resulted in a reduction in time for completion of laboratory work compared with the time taken by a control group with no CAL experience. In four of the experiments the time reduction was between 20-26 minutes out of a scheduled four hours laboratory session.

The literature survey revealed several kinds of pre-lab work/activities for example, (a) reading the laboratory manual before starting the experimental work, (b) solving theoretical problems relating to the experiment before coming to the lab course, (c) doing computer simulations of experiments, (d) listening to a short talk about the most important points of experiment in the first half hour of the lab session, (e) understand audio-visual preparation and so on.

According to Arends (2004), the major pedagogical strategy proposed by Ausubel was the use of advance organizers. It is the job of the organizers to: “Delineate clearly, precisely, and explicitly the principal similarities and differences between the ideas in a new learning passage, on the one hand, and existing related concepts in cognitive structure on the other.”

“An advance organizer is information that is presented prior to learning and that can be used by the learner to organize and interpret new incoming information (Mayer, 2003).” These organizers are introduced in advance of learning itself, and are also presented at a higher level of abstraction, generality, and inclusiveness; and since the substantive content of a given organizer or series of organizers is selected on the basis of its suitability for explaining, integrating, and interrelating the material they precede, this strategy simultaneously satisfies the substantive as well as the programming criteria for enhancing the organization strength of cognitive structure."

Organizers act as a subsuming bridge between new learning material and existing related ideas." Students' preparation before starting practical work should increase the chances of their understanding what they are doing in the lab. This is intended to avoid a 'cook book' or 'recipe following' scenario. (Zaman, 1996)

According to Shah (2004), "Optimal learning generally occurs when there is a potential fit between the student's schemas and the material to be learned. To foster this association, Ausubel suggests that the lesson always begin with an advance organizer- an introductory statement of a relationship of high-level concept, broad enough to encompass all the information that will follow. The function of the advance organizers is to provide scaffolding or support for the new information. It is a conceptual bridge between new material and a student's current knowledge."

Ausubel (1968) stated "if I had to reduce all of the educational psychology to just one principle, I would say this; the important single factor influencing learning is what the learner already knows." Keeping in view the above-cited statement, the pre-labs for twenty experiments were developed by highlighting the essential ideas related to the work to be done and used as an advance organizer to facilitate meaningful learning. Each pre-lab was presented to the students well in advance 2 to 3 days before the actual laboratory work. The pre-lab was used to help students learn about their knowledge construction, that is the linkage between the guest (post-lab) and the host ideas/concepts (pre-lab).

Hypothesis of the Study

There is no significant difference between the achievement of the students with pre-lab as advance organizers and students without pre-lab in the post labs results.

Methodology

The sample of 62 secondary school students was drawn and then divided in two equivalent groups on the basis of the marks achieved from the 8th class science. The marks were arranged in descending order with serial numbers, 1, 2, 3, 4, 5, 6… and, then divided into two equivalent groups on the even/odd basis (i.e. rank order 1,3,5,7….control group, and 2,4,6,8….experimental group)

According to the nature of the experiment and in the perspective of the psychological models of learning science, pre-lab sheets were developed for twenty experiments. These pre-labs were constructed under the headings and responses such as: (a) what does it do? (b) How does it work? (c) What will it measure? (d) What should I know before I begin? (d) …. And so on. Some other supplementary but necessary information was also provided to the students, according to the demands of the experiment. One pre-lab and one post lab is shown in the appendix-A.

The aim of the pre-labs was to prepare the students to take an intelligent interest in the experiment and make the material more understandable for the students by knowing where they are going, why they are going there and how they are going to get there. In developing the set of twenty pre-laboratory exercises used here, the first step was to look at the experimental work in detail and to define the key underlying ideas which would be necessary to make sense of the work. The specific pre-laboratory tasks were then design to ensure that these key ideas were understood. The set of pre-laboratory exercises were given to several experienced staff members, experts related to the field of science education for comments and then adaptations were incorporated.

Ausubel (1968) stated "if I had to reduce all of the educational psychology to just one principle, I would say this; the important single factor influencing learning is what the learner already knows." Keeping in view the above-cited statement, the pre-labs for each experiment was prepared by highlighting the essential ideas related to the work to be done. The pre-lab was used to help students learn about their knowledge construction, that is the linkage between the guest (post-lab) and the host ideas/concepts.

The research work was carried out for the period of thirty-five weeks in the secondary school physics laboratory. In the physics laboratory the students came once per week for one and half an hour. The control group came on each Saturday from 8:30 to 10:00, and the experimental group came from 10:00 to 11:30 in the physical science laboratory for practical work. A lecture of one hour in the form of pre-lab (as advanced organizer) along with hand out was delivered to the experimental group by the researcher at least three days before the actual laboratory work. Each student with pre-lab was expected to do some preparatory work before he came to the laboratory.

To find the effectiveness of the pre-lab, some more work in the form of post-lab was administered to the whole sample (i.e. experimental & control) after the end of each practical. There was a great flexibility in the system that if any student was unable to attend one of his pre-lab/post-lab due to any reason, he was invited to attend on the next day. The post-labs consisted of some written work, objective type test- items, and some practical activities.

The timetable was prepared and adjusted with the regular timetable of the school.

The posttest only equivalent group design was used for this study. It involved two groups; experimental and control.

The symbolic representation of the research design is:

$$\begin{array}{lcl} R\ E & = & T \quad O_1 \\ R\ C & = & - \quad O_2 \\ \text{Difference} & = & O_1 - O_2 \end{array}$$

R = randomly selected; E = experimental; O = observation C = control; T = treatment

Matched Group	Class	No. of Students
Experimental	X	31
Control	X	31

Age Group of Sample: 14 ½ to 16 ½ Years

Independent Variables (Treatment Variables): pre-labs as advance organizers

The t-test is a convenient way to find out the significant difference between the two mean scores at a selected probability level; that is, for a given sample size the 't' indicates how often a difference (between the mean scores of experimental and control groups) is larger or larger would be found when there is no true population difference.

Data Analysis

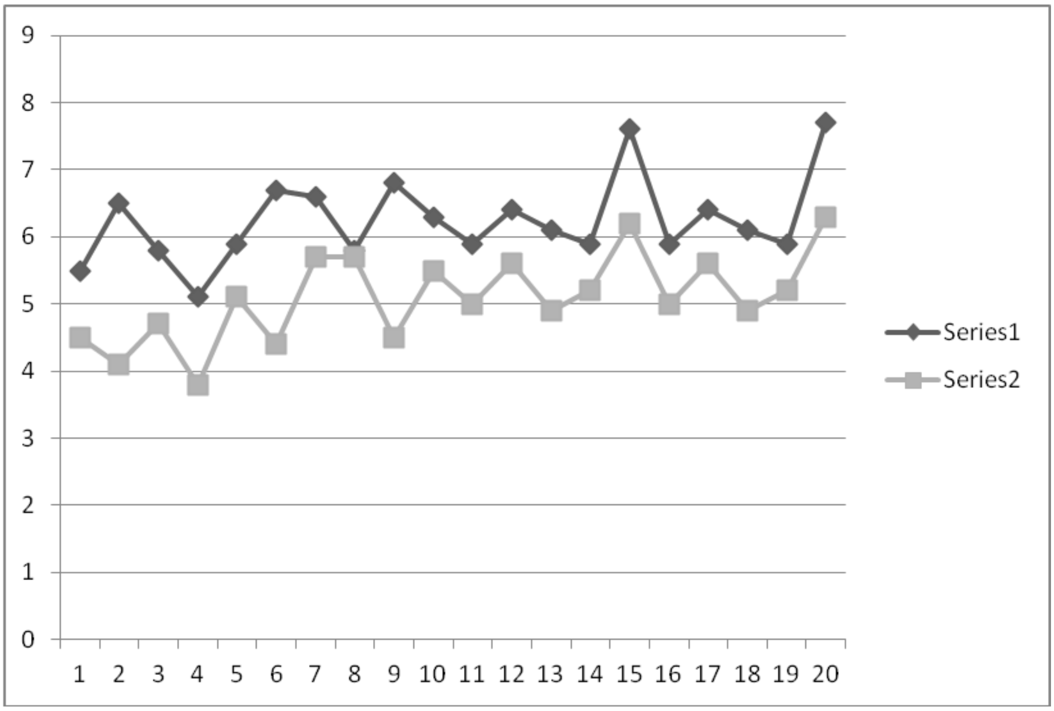
Table 1. Summary of the post-lab results of experimental and control groups

Laboratory Experiments	**Experimental** (with pre-lab) N = 31		**Control** (without pre-lab) N = 30		**Comparison**	
	Mean	*SD*	*Mean*	*SD*	*t-test*	*p*
1. Diameter of a solid cylinder	5.5	1.9	4.5	1.9	2.02	<.01
2. Thickness of a given wire	6.5	1.7	4.1	1.6	5.58	<.001
3. Acceleration of a body	5.8	1.9	4.7	1.7	2.30	<.05
4. M.A of an inclined Plane	5.1	1.7	3.8	1.4	3.08	<.01
5. Principle of moments	5.9	2.0	5.1	2.2	1.76	>.05
6. Resultant of two vectors	6.7	1.6	4.4	1.7	5.57	<.001
7. Verify Hook's Law	6.6	1.7	5.7	1.2	2.55	<.05
8. Density of a body	5.8	1.5	5.7	1.3	0.20	>.05
9. Simple pendulum	6.8	1.5	4.5	1.2	5.27	<.001
10.Speed of sound	6.3	1.6	5.5	1.1	2.25	<.05
11.Verify Ohm's law	5.9	1.3	5.0	1.3	2.72	<.01
12.Plot Magnetic field	6.4	1.3	5.6	1.7	2.03	<.05
13.Densityof solid heavier then water	6.1	1.5	4.9	1.3	3.18	<.01
14. Characteristics of P-N junction.	5.9	1.5	5.2	1.1	2.01	<.05
15. Truth table of AND & OR gates.	7.6	1.4	6.2	1.4	3.79	<.001
16.Laws of Reflection	5.9	1.3	5.0	1.2	2.71	<.01
17.Laws of Refraction	6.4	1.3	5.6	1.7	2.03	<.05
18.Focal length of a concave mirror	6.1	1.5	4.9	1.3	3.18	<.01
19.Focal length of a convex Lens	5.9	1.5	5.2	1.1	2.01	<.05
20.Critical angle of glass	7.7	1.4	6.3	1.4	3.79	<.001

Table 1 shows the statistics of twenty experiments exploring the effect of pre-lab on the learning of the students. A paired sample t-test was conducted to evaluate whether there was any significant difference between the mean score achieved by the students with pre-lab and without pre-lab. The result indicated that the mean concern for Students with pre-lab was significantly greater than the mean concern for Students without pre-lab. It is indicated that students with pre-lab performed better than the students without pre-lab.

Results revealed that the experimental group out performed in the post-lab results as compare to the control group in almost all the experiments except No. 5 & 8, in the subject of physics. A clearer picture of the above data is shown in the figure 1.

Figure 1



Discussion

Literature reviewed showed almost same results as evidenced by the researchers conducted by Zaman (1996), Johnstone and Zaman (1998), and some others but mostly at university level. This study is specifically consistent with the findings of shah (2004) and Limniou (2008). Since the results are consistent with the results of the above cited researches, hence, we concluded that the pre-labs as advance organizers help the students in improving the performance of student in the physical science laboratory.

This work is in line with the majority of the previous studies, resulted in favour of pre-lab. The superiority of this approach could be attributed to the active participation of students in all processes of learning in the laboratory. This develops a positive attitude toward the physics, and consequently results in high performance. Conversely, expecting students to engage in laboratory activities without some form of prior consideration may leave them feeling insecure, and result in a rather poor understanding of what is happening. Students often have difficulty in completing the necessary calculations relevant to the experiment and results in poor performance.

If we look into the table 1, it is also very interesting that the standard deviation of the students with pre-labs (i.e. of Experimental Group) has range 2.0 -- 1.3 = 0.7 which shows that some students learn more and some learn least. This gives rise to the idea of students' learning styles, which should be explored in future.

The persistent increase in the standard deviations obtained for the experimental group also suggests that not all students are benefiting equally. There is a need to explore this further by looking at the learner characteristics of that group which benefited least by the new approach. Actually, it would be worth looking at individual students to see whether there are any discernable patterns among those in the experimental group who did exceptionally badly.

Post-labs, although used for measurement purposes, almost certainly have an important function in consolidating what was learned in the lab, and helping the students to link new knowledge to existing knowledge (Zaman, 1996, Johnstone and Zaman, 1998, Limnious, 2008).

Conclusion

From the above discussion, it is concluded that the pre-labs significantly help the students to improve their performance in the physics laboratory. Since post-labs were testing the understanding of principles encountered in the laboratory and also testing their use in unfamiliar situations, improvement in post-lab performance is a good indication of learning gain from the laboratory experience.

The role and value of pre-lab and post-lab experiences is well documented in the literature but mostly at university level. This study is consistent with past findings but at school level and is also specifically consistent with the findings of shah (2004). Hence, it is recommended that this approach be adopted widely at secondary level in Pakistan.

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APPENDIX-A

Pre-lab "Simple Pendulum"

What will I measure?

You will measure:

1. The diameter of the bob with the help of vernier callipers.
2. The total length of the simple pendulum.
3. The total time for thirty vibrations.
4. The time- period of the simple pendulum.
5. Average length of the pendulum.
6. Average time-period of the pendulum.

What should I know before I begin?

1. How to measure the diameter of the bob? (See the enclosed page)
2. How to calculate the total length of simple pendulum?
3. How to find the total time for thirty vibrations?
4. How to calculate time-period?
5. The relationship between length (1) and time- period (T).

   (See the enclosed page and consult your practical notebook)

II. There are two scales on the vernier callipers.

1. Main scale 2. Vernier scale

The smaller division on the main scale is in millimeter. The length of the vernier scale is 9 mm, which is divided into ten equal division of vernier scale (i.e.0.9 mm=1division of vernier scale)

Smallest division of main scale = 1mm

Smallest division of the vernier scale = 0.9mm

Least count (L.C.) or Vernier Constant (V.C.)

Least count = smallest division of main scale – smallest division of vernier scale

= 1 mm – 0.9 mm

= 0.1 mm or 0.01 cm

Least count can also be calculated from the formula given below

L.C or V.C = smallest division on main scale / total no. of divisions on the vernier scale

= 1mm / 10

= 0.1 mm = 0.01 cm

III. Now bring the jaws D and C in contact with each other. If the vernier zero exactly coincides with the main scale zero, there is no instrumental or zero error. (See fig. a) But if it is otherwise, there is error.

Figure (a)

Note the position of the vernier zero while the jaws are in contact. If the zero of the vernier scale lies on the right of the main scale zero, the error is positive but the correction would come out to be negative, which means that it is to be subtracted from all subsequent readings of the instrument.

Figure (b)

At the position of contact, if vernier zero is to the left of main scale zero, the error is negative and the correction is positive. In order to find the positive error, look at the vernier scale from left to right and note the number of the particular division, which coincides with any main scale division. Multiply this number with vernier constant. The product would give the positive error. For example, in Fig. (b) The 7^{th} division of the vernier scale coincides with some main scale division. Therefore the positive error is:

7 x 0.1 mm = 0.7 mm or 7 x 0.01 cm = 0.07 cm.

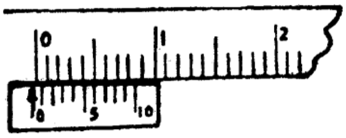


Figure (c)

To determine the negative error, look at the vernier scale from left to right and note the number of the particular division, which coincides with any main scale division. Subtract this number from 10. Multiply the remainder with least count to obtain the negative error. For example in Fig (c), the 6^{th} division of vernier scale coincides with some main scale division. Therefore the negative error is (10 – 6) x 0.1mm = 0.4mm or 0.04cm.

How to measure the radius of the bob?

Determine the zero error of the vernier callipers if any and then get the zero correction. Open the jaws and put given bob in them in such a way that the jaws touch the ends of the bob. Read the main scale reading to the left of the zero line of vernier scale, this gives the complete main scale division in centimeters.

Note the number of particular division, which joins with any of the main scale division. Multiply this number with vernier constant this gives the complete vernier scale division in centimeter. Add the main scale reading in vernier scale, this gives the observed diameter of the bob. Take three observations at three different points and apply zero correction to get correct value of diameter. Calculate the mean diameter and then calculate the radius ‘r’ by dividing the diameter by 2 (r = d/2)

Find the zero error in this figure?

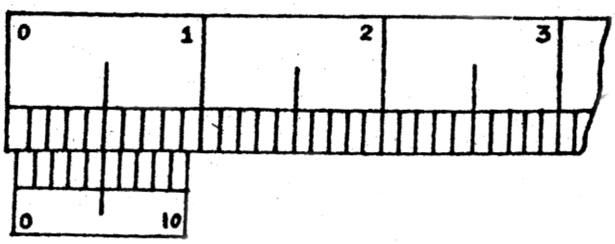


Figure (d)

What is the reading in this figure?

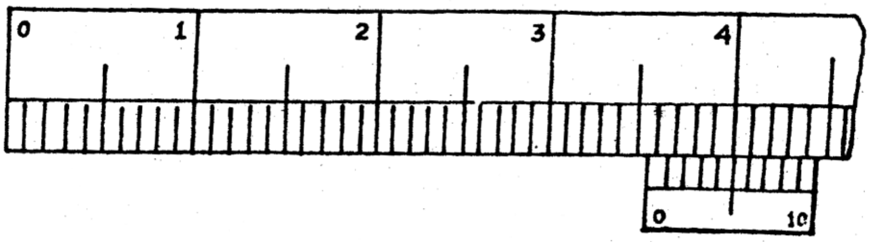
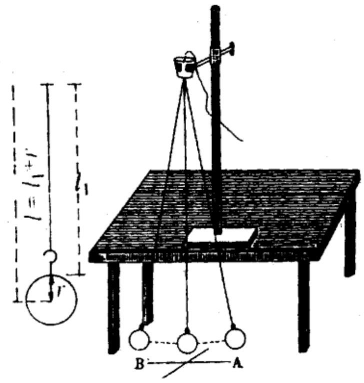


Figure (e)

Procedure:

Take a fine thread about 100 to 150 cm long and rub it with cobbler’s wax to avoid rotatory motion of the bob due to the twists of the thread. Tie one end of the thread to the hook of the bob and other end between the spaces of the spilt cork and tie it firmly to an iron stand. Place the iron stand on the table in such a way that the bob is just a few centimeters (2 – 4) above the floor. Mark two points A and B at a distance of nearly 5cm as shown in the figure f. Take the bob to one of the points A or B and release it very gently. It will start vibrating.

Simple Pendulum



Take a Stop Watch. Study its scales. Hold it in your hand.

How to count vibrations?

Watch the motion of the bob. When it just passes from the mark O, start the Stop Watch. When the bob crosses point O again in the same direction, one vibration has been completed. In the same manner, count 30 vibrations. Stop the watch just when the 30th vibration has been completed. Note the time taken by the bob to complete 30 vibrations. Repeat it again without changing its length. Find the mean time for 30 vibrations. Calculate time- period T that is the time for one vibration.

Measure the length of the pendulum ($l = l_1 + r$).

After noting T and l in the table, study the relation between them.

Repeat experiment with different length and find l/T^2 in each case.

Check that $l \; \alpha \; T^2$ or $l / T^2 =$ Constant

<u>POST-LAB "THE SIMPLE PENDULUM"</u>

The following questions will help you to consolidate the work you did in the lab and help us to improve the teaching – learning process in the lab.

(Part A) (6x1 = 6)

Read the statements carefully and tick (✓) the correct answer.

1. The time- period of second pendulum is:

(a) 0.02 sec. (b) 0.2 sec.

(c) 2.0 sec. (d) 2.2 sec.

2. A simple pendulum is made of plastic ball (as a bob) filled with water and have a hole in it. During the oscillation, due to the flow of water, its mass decreases. What will be the effect on the time- period of the pendulum? (Law of mass of simple pendulum)

(a) It will increase (b) It will decrease

(c) It will remain same (d) none of the, a, b, c.

3. If the bob of the pendulum of given length is replaced by another bob of different material what will be the effect on the time -period of the pendulum?

(a) It will increase (b) It will decrease

(c) It will remain same (d) none of the, a, b, c.

4. If the oscillation of a simple pendulum of a given length became small. What will be the effect of smaller oscillations on the time- period of the pendulum? (Law of isochronisms)

(a) It will increase (b) It will decrease

(c) It will remain same (d) none of the, a, b, c.

5. If we decrease the length of the simple pendulum. What will be the effect of length on the time-period of the pendulum? (Law of length)

(a) It will increase (b) It will decrease

(c) It will remain the same (d) none of the, a, b, c.

6. Second pendulum is one whose time-period is two seconds. What is its frequency?

(a) 0.5 Hertz (b) 1.0 Hertz

(c) 1.5 Hertz (d) 2.0 Hertz

(Part B) (2x1 = 2)

Write the short answers (on the space given below) of the following questions.

1. Will a pendulum of a clock that keeps correct time at Karachi, be accurate at the mountain K2.

2. Give two examples of motion's that are simple harmonic.

(Part C) (2)

By using formula $T = 2\pi \sqrt{l/g}$ Find the value of g by taking the mean length (l) and the time-period (T) from your experiment you have just done. Is it 9.8 m/s^2 (approximately)?