BOSE AND RAMAN'S WAYS IN THE CLASSROOM: DEMONSTRATING THE DEATH OF PLANT CELLS AND MAGNETS

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Living cells have specific structural organisation which in turn is a reflection of molecular configurations. Heating beyond a limit destroys that organisation causing death. Pasteurisation, which is the process of sterilisation by heat, has been possible because of this reason. Molecular configurations of most of the germ cells are damaged severely above a certain temperature. So the germ cells die.

Science cannot be learnt (or taught) just by reading or discourse. Science can be learnt only by doing and by observing. Hands-on experiments and classroom demonstration are part and parcel of science teaching. All through the history of modern science, good teachers and scientists supplemented their lectures with practical demonstrations. Even in the early days of modern science in India, pioneering scientists innovated classroom demonstrations. In this respect, Jagadish Chandra Bose (1858-1937) and Chandrasekhar Venkat Raman (1888-1970) marvelled.

J.C. Bose was a Professor of Physics at the Presidency College, Calcutta for more than thirty years. C. V. Raman was also a Professor of Physics in the University of Calcutta for almost twenty-five years.

J. C. Bose

Jagadish Chandra Bose is commonly known as J.C.Bose. He was born on 30 November, 1858 in East Bengal, now Bangladesh. After doing B.Sc. from the St. Xaviers' College in Calcutta he went to England for higher studies. He completed his tripos examination from the Cambridge University in 1884. Simultaneously he obtained B.Sc. degree of the London University. He came back to India and joined Presidency College as Professor of Physics in 1885. *He retired* in 1915 but stayed there for two more years as *Professor Emeritus*. In 1917 he founded the Bose Research Institute (Basu Vijnan Mandir) in Calcutta for higher research. He was the *Director* of the Institute till his death on 23 November, 1937.

J.C.Bose started researches in small radio waves. The field is now called micro-wave physics. Indeed Bose was one of the earliest microwave physicists. In 1902 he shifted his research interests to plant physiology and plant bio-physics. He innovated a number of high precision instruments for his researches. He is considered as the forerunner of modern biophysics. He won many honours including Fellowship of the Royal Society of London (FRS) in 1920.

Both of them were teachers per excellence and splendid experimentalists. Their lectures in the classroom were always accompanied by experimental demonstrations. They innovated simple experiments with easily available materials. They were also very good at public lectures on science, these lectures were often accompanied by practical demonstrations. Two such experimental demonstrations, one by Bose and another by Raman, are described here. *Bose's experiment demonstrated the death of plant cells by heating. Raman demonstrated demagnetisation of permanent ferromagnets by heat. Demagnetisation may be considered as death of a magnet. Death of a living body and demagnetisation are both irreversible processes. That means they cannot regain life or magnetic property just by reversing the process by which (here, rise in temperature) death or demagnetisation was caused.

*** The author learnt about Bose's experiment personally from N.S.Sen (1883-1972) who was a long time research assistant to Bose and about Raman's experimental demonstration from M.M.Ghosh (1906-1991) who was taught by Raman when the former was doing post-graduation.**

Effect of Temperature

Significant changes in temperature bring about physical and chemical changes in a material body. Temperature is the indication of molecular motion or molecular and atomic disturbances within a substance. Living cells have specific structural organisation which in turn is a reflection of molecular configurations. Heating beyond a limit destroys that organisation causing death. Pasteurisation, which is the process of sterilisation by heat, has been possible because of this reason. Molecular configurations of most of the germ cells are damaged severely above a certain temperature. So the germ cells die.

Non-living matters also show interesting changes. Molecules or rather atomic configurations of crystal lattice in a magnet are organised in certain specific manner. Heating starts disturbing this lattice configuration, with rise in temperature a permanent magnet starts losing its magnetic property. As a specific high temperature, called Curie point or Curie temperature, magnetism is completely and abruptly lost. Curie temperature is specific for a specific type of magnetic material.

Curie Point

Curie point or Curie temperature is the temperature at which ferromagnetic material loses its magnetism. Above Curie temperature, the material usually behaves as a paramagnetic material. The name is from Pierre Curie (1859-1906) who discovered this phenomenon in 1895. In that year he married Mary Curie (1867-1934). They together got the Nobel Prize in 1903 for their work on radio-activity. Curie Points of some of the well-known ferromagnetic materials are as follows.

Ferromagnetic material	*Curie point in °K*	*Curie point in °C*
Magnetite or magnetic oxide of iron	843	570
Iron (Fe) (Steel)	1043	770
Cobalt (Co)	1388	1115
Nickel (Ni)	631	358
Gadolinium (Gd)	289	16
Dysporsium (Dy)	85	-188

In each case of death or change of a stable property (such as magnetism) there is a sudden jerking end. Just before the end comes there is a severe, quick molecular change and sharp violent or erratic response. J.C. Bose called it the death spasm. The experiments described here can be shown by teachers as classroom demonstrations in school or in science exhibitions by students.

Bose's Demonstration

Bose took a stem of some length from a live creeper plant like pumpkin. With a sharp razor blade or knife the stem was cut in the form of a spiral. This was then put in cold water (at room temperature) in a beaker of appropriate size and securely held. The water should not fill more than two-thirds of the beaker. The upper end of the stem thus prepared was fastened to string or thread of sufficient strength. The beaker was placed on a stand at a suitable place so that it could be heated by a soft flame. The string was vertically held from a hook in the ceiling of the room or by means of support. A small mirror was attached to the string at a suitable height above the beaker. Such mirrors are easily available as are used for decorating ladies handbags. The arrangement was similar to the mirror arrangement of a reflecting string galvanometer. A sharp pencil of light was made to fall on the mirror from a strong source of light. The reflected light pencil was received by a screen. A wall of the room could also be used as a screen. A thermometer (which could read up to 100° C) was put in the beaker.

The demonstration room was made dark, so that the movement of the reflected light spot on the screen could be clearly visible. Only a small light showed the beaker and the thermometer. The water in the beaker was then heated gradually with a soft flame. As the temperature rose, the spot of light started moving in a slow pace. When the temperature was above 60°C the pace of movement increased. At temperature above 60°C the movement became violent, the light spot shot to other side and then stood still. With further rise in temperature the light spot did not move. It meant that the plant cells had died with a spasm. One could read the temperature at which the spasm started and when exactly the end came. It is the temperature at which pasteurisation is best performed (see box).

Pasteurisation

Pasteurisation is a process which is used to prevent spoiling of liquids such as beverages or milk. The process can be affected in two different ways. In the first, the liquid is heated at about 60-65°C for 30 minutes. Otherwise it may be heated up to 75°C for only 15 seconds. In this way the living bacteria which cause spoiling are destroyed but the flavour, taste, etc., are retained; vitamins are also preserved.

The process got its name from the name of Louis Pasteur (1822-1895). Pasteur was a great French scientist and one of the proponents of germ theory of disease. During 1860's he was approached by the persons in brewery industry to solve the problem of spoiling of wines and beers. He found that the process of fermentation by which sugars and carbohydrates are transformed into alcohol are caused by certain bacteria. Alcohol (ethyl alcohol) is the main ingredient of wines and beers. If the bacterial activities were allowed to continue, there was over-fermentation and the beverage might become spoiled.

After many trials Pasteur was able to find the solution sterilisation by heating. The word pasteurise as a verb to mean the process was first used in 1881. The term pasteurisation was used for the first time on 21st October, 1886 in the newspaper *Times* of London.

When Pasteur did his experiments on sterilisation of liquids (first with brews or wines), he did not think of the death of plant cells. But most of the germs which are bacteria are nothing but microbial plants. When J.C.Bose innovated this experiment, he did not link the death temperature with temperature of pasteurisation. But well, the connection is apparent.

If the flame was removed and the temperature allowed to go down, there would not be any movement of the light spot in other direction. The process is irreversible. One could be more sure by taking sectional samples from the stem before and after the experiment and comparing them under a suitable microscope.

Raman's Demonstration

C.V. Raman

C. V. Raman was born in Madras on 7 November, 1888. He was a brilliant student all through. He passed Matriculation examination at the age of eleven and half years. He passed M.Sc. examination in Physics from the Madras University at the young age of 18 standing first class first in the order of merit. He published research papers in famous international journals even when he was a student.

He then appeared in all-India examination for Financial Service of the Government of India. He stood first in that examination also. He was posted in Calcutta as Assistant Accountant General. He was in this service for ten years. But he continued doing research in physics in his spare time. This did not go unnoticed. In 1916, he was directly appointed as Professor in the University of Calcutta. He remained there till 1933 when he moved to the Indian Institute of Science, Bangalore. In 1947 he established Raman Research Institute in Bangalore and remained there as Director till his death on 21 November, 1970.

Raman along with his student K.S. Krishnan started working on scattering of light by liquids in 1925. In 1928 they discovered Raman's effect. In 1930 Raman was awarded the Nobel Prize. Till now he is the only Indian to have received the Nobel Prize in Science working in India. He was elected F.R.S. in 1924.

For demagnetisation experiment of Raman, a strong permanent bar magnet was taken. Its length should be between 20 and 50 cms. The magnet was tightly held in the middle by a support. The two ends were kept free. At the one end there was arrangement for strong heating. Near the other end a soft-iron ball was suspended by a string. The string might be a metallic wire (but not of steel which might have some magnetism) or a good cotton thread. Now-a-days threads of synthetic materials such as nylon or PVC are available. But they should be avoided. Such a precaution is necessary because a string of synthetic material may be affected by heat.

The weight of the soft iron ball should be appropriate. The ball should have a hole through it like the beads of a necklace or it should have a hook for fastening the string. In Raman's days such balls were not readily available and were to be fabricated. But one may now buy one or get one from a junk store even.

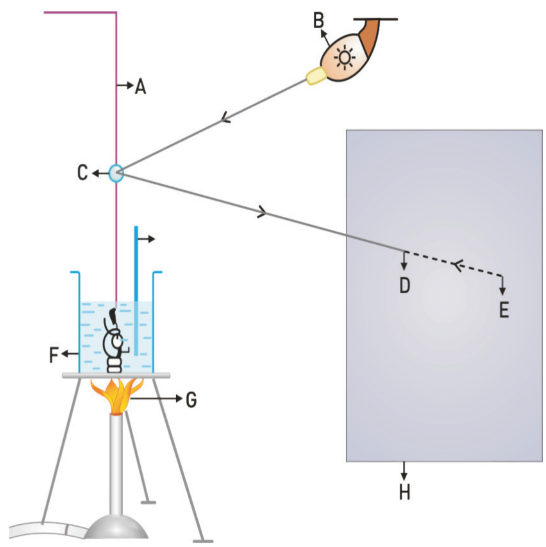
Even the ball was suspended near one end of the magnet (opposite the end where heating lamp or burner was placed) in an appropriate position, the ball was attracted to the magnet and stuck to it.

The other end was then heated by a strong flame. After a while the iron ball started to shift away slowly from the magnet. When the Curie point was reached the ball flung away with a jerk and started swaying like a pendulum. After some time it was vertically hung having the only attraction of gravity. Then the flame was put off. The magnet was set to cool. Even after cooling there was no return of magnetic attraction. Demagnetisation is an irreversible process.

One point is important here. One cannot use a simple thermometer to note or measure the Curie point as the Curie points of all the available ferro-magnetic materials are several hundred degree celsius. Raman could do it by some sophisticated thermometer such as a radiometer or a thermocouple thermometer of suitable range. If a thermometer which can read up to 1000°C be available, Curie temperatures can be shown.

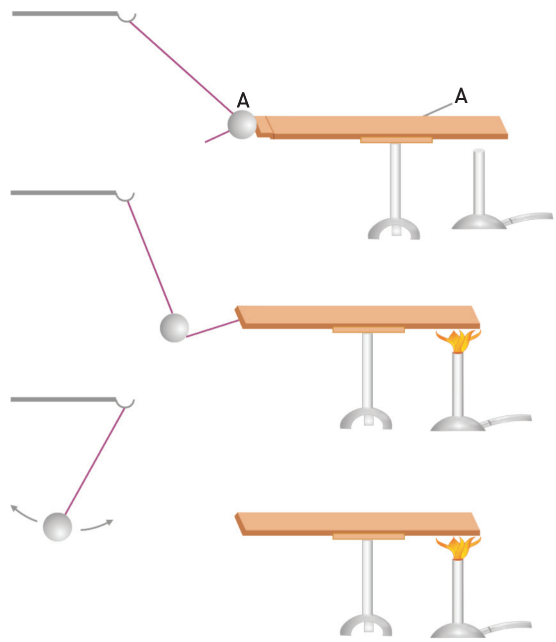
Any teacher wanting to use this classroom demonstration, should remember another point. Every time this experiment is to be performed, a permanent magnet is to be sacrificed. Or, if one likes to show different Curie points for different materials, one should be prepared to sacrifice several magnets. These differences in Curie points can be shown directly by using a suitable thermometer. However, for want of a thermometer an imprecise indirect method may be used. By keeping the heating flame in the same state and noting down the time taken for demagnetisation (the point of jerked swaying) the differences can be illustrated. It is advisable that one should make some arrangement for magnetizing the bar each time after the experiment so that the same bar magnet can be used again and again.

The experiments described here are comparatively easy. One should however remember that for every experimental set-up, there are a number of problems and hazards, minor and major which are to be faced and overcome. Before the first successful result, there may be many failures.



J.C. Bose's Experimental Demonstration on Death Spasm of Plant Cells

A: Thread	D: $\geq 60°$	G: Soft flame
B: Light source	E: Start	H: Screen Wall
C: Mirror	F: Strongly held plant stem	



C.V. Raman's Experimental Demonstration on Death of Magnet (demagnetisation) by heating to Curie point
A: Iron ball B: Permanent magnet