



Learning Science via Standards



Ballpoint Pen



IS 3705

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Lesson 21
July 2023



Nurturing Young Minds as Ambassadors of Quality and Standards



Foreword

Everything around us, whether natural phenomena or manmade products can be explained through science. The product which are used in our daily life are outcome of conscious efforts by the mankind to fulfil and exceed the needs of the present and demands of the future. Students are taught science as part of their school curriculum, to enable them to understand the various scientific laws and principles and also to inculcate the habit of exploring the world through the lens of science. Quality characteristics of any product or service are decided based on the stated and implied needs and are generally described in a document called 'Standard'. Science and standards are inseparable and integral aspect of any product.

Bureau of Indian Standards (BIS), the national standards body of India, is mandated for establishment and promotion of standards and creating a quality ecosystem in the country. This is achieved through developing Indian Standards on products and services through the active involvement of relevant stakeholders and dissemination of information of such standards for their use and implementation across all sectors of economy. Academia, as an important stakeholder of BIS, has been contributing towards development of standards through research activities and providing inputs related to technological advancements in product development, their characteristics and use as well as methods of tests. BIS, on its part has also been promoting standards in academia through a variety of programmes. This has since been institutionalized in the form of "Standards Clubs" which are being established in educational institutions across India to nurture the young minds as ambassadors of quality and standards and prepare them for dealing with these aspects in future.

In this initiative of BIS, called "Learning Science via Standards", a series of Lesson Plans are made elaborating the various scientific concepts, laws and principles to help students understand their practical applications via standards. The series comprises of a variety of subjects for insights into the scientific laws and principles and relating them to the quality characteristics of products used in day-to-day life. First 10 Lesson Plans in the series are released on the occasion of World Consumer Rights Day on 15 Mar 2023. Second Set of 10 Lesson Plans were released on 10 Jun 2023 by Hon'ble Minister of State during the Governing Council Meeting of BIS.

The Lesson Plans are expected to serve as a useful tool for the teaching fraternity for imparting knowledge on scientific laws and principles through their practical applications in activities and products around us and facilitate an interactive learning experience for the students.



Ballpoint Pen

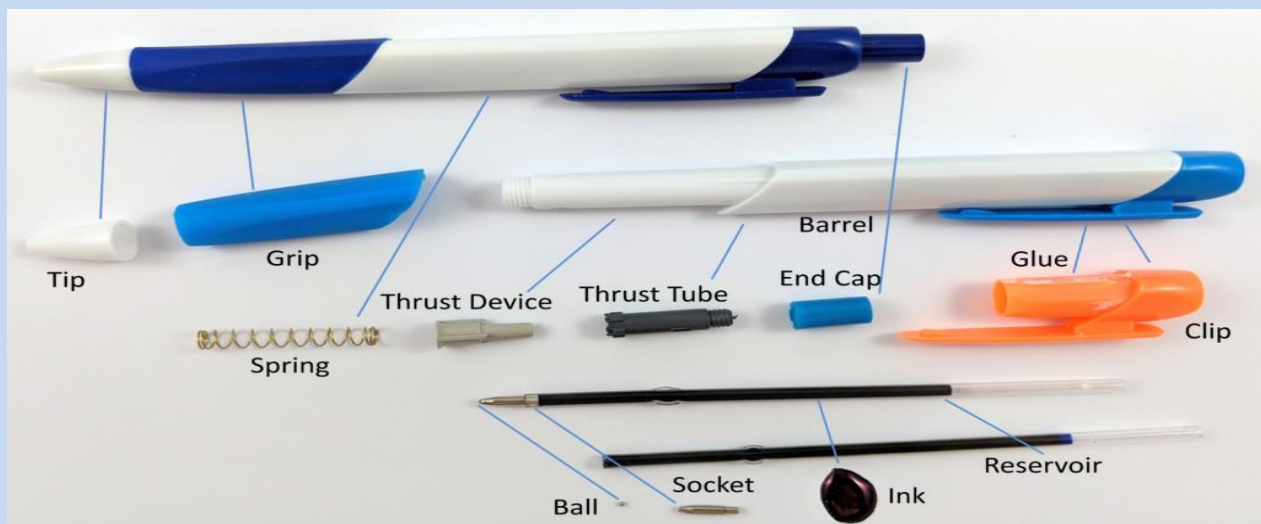
A ballpoint pen is a writing tool with a tip which is supplied continuously with ink. The pen consists of a metal ball positioned in a socket underneath an ink supply (the chamber or tube containing an ink supply also known as ink cartridge). The ink tank is known as an ink cartridge. The ball rotates when applied to a writing surface and is bathed with just enough ink to write easily. The main motive behind making of ballpoint pen was to have a writing instrument that would write not only like a normal fountain pen but on rough and hard surfaces as well.

A freely rotating ball at the tip of the pen sits on a socket. The part that is used for writing is exposed, while the rest stays inside the pen. When the pen tip is applied to a writing surface, the ball rolls, transferring ink from the ink reservoir to the writing surface.

The ballpoint pen was developed as a solution to the problems of using a fountain pen for writing. Fountain pens need constant refilling with ink. The ink may leak or clog up the pen. The ballpoint pen, on the other hand, has its own ink supply which uses capillary action (a liquid's rising action through a tube) to keep the ink from leaking out.

The history of a Ballpoint pen can be traced back in the year 1888 when its first patent was made. However, commercial availability took almost a half-century. The first patent for a ballpoint pen was issued on 30 October 1888 to John J. Loud, who was attempting to make a writing instrument that would be able to write". Two Hungarian brothers, Laszlo (1899–1985) and Georg Biro invented a ballpoint pen in the 1930s, using the thick ink used in newspaper printing. Laszlo had found this sort of ink was drying quickly. Hungarian journalist Biro well understood about typical pens issues and contributed to development of pen.

1. Components of Ball Point Pen



In the modern world, there are some changes in the components of a ballpoint pen however the basic structure remains same. Ball point pen is commonly composed of Tip, Grip, Decorative Ring, Barrel, Clip, Ink Chamber/Refill, Twist/Thrust Mechanism including spring and Ballpoint Tip.

Ballpoint Pen Tip is what makes it a ballpoint pen. At the tip, a freely rotating ball is held in a small socket which connects it to an ink reservoir that allows the pen to write or draw lines. The tip is commonly made up of metals/metal alloys such as steel, brass or tungsten carbides. The diameter of the ball typically is in the range of 0.7mm to 1.15mm and are commonly classified as fine, medium and broad.



The Grip of the ballpoint pen is used to make it more convenient. It is usually made of rubber, an elastic substance so that the ballpoint pen can be held with ease and comfort. Rubber has good friction against the human skin. A smooth metallic surface on the other hand needs application of more pressure for holding firmly.

The Barrel simply covers what is inside and that is, the ink chamber, thrust or twist mechanism etc. It is the foundation of the clip so that the ballpoint pen can be hung or clipped properly.



Ink Chamber/Reservoir is the storage of ink. The ink of the ballpoint pen usually contains solutions of dyes, with organic solvents such as propylene glycol, propyl alcohol etc. Common dyes in blue ink are Prussian blue, Victoria blue, Methyl violet, etc..

Twist or Thrust Mechanism is used to get in and out the ballpoint tip when it is needed. It is like a switch where you turn the ballpoint

pen on or off thereby saving the tip of pen from damage when not needed.

Ballpoint Pen Clip is the holder of the ballpoint pen. Clip can be found in the upper part of the ballpoint pen and is used to clip or hang the pen to the shirt, pocket or even bags.

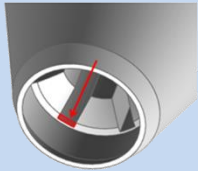
2. Manufacture of Ballpoint Pen Ink

- a) **Formulating:** The first step is to formulate the ink, which involves selecting the right combination of dyes, solvents, and additives. The dyes give the ink its color, the solvents make the ink flow smoothly, and the additives help to keep the ink from drying out too quickly or clogging the ball tip.
- b) **Mixing:** Once the ink formula has been finalized, the dyes, solvents, and additives are mixed together in a large tank. The mixing process is typically done using a high-speed mixer that ensures that the ingredients are evenly distributed.
- c) **Filtering:** After the ink has been mixed, it is filtered to remove any impurities. The filtering process is typically done using a series of filters that remove particles of different sizes.

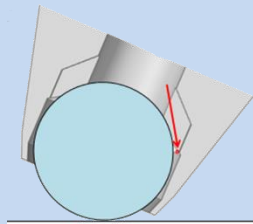
- d) Packaging:** The filtered ink is then packaged in bottles, cartridges, or other containers. The packaging process is typically done using automated machinery.

3. Working Principle of Ball Point Pen

The working principle of a ballpoint pen involves a combination of gravity, capillary action, and rolling friction. Here's a breakdown of how it works:



Capillary action: The nib/tip has a small hole, usually in the range of 0.5 to 1.2 milli meters in diameter, through which the ink flows. Capillary action, which is the ability of a liquid to flow in narrow spaces without the assistance of external forces like gravity, allows the ink to be drawn out of the reservoir and onto the ball.



Rolling friction: When you write or draw with a ballpoint pen, you apply pressure on the ball against the writing surface. As the ball rotates, it rolls across the paper, leaving a trail of ink behind.

Ink Flow Control: The ink does not flow out of the pen freely due to its viscous nature. Instead, it relies on the rolling friction between the ball and the paper to create enough force to push the ink out around the ball. This controlled flow of ink ensures that the pen does not leak or create smudges when not in use.

Replenishing ink: As the ink is used, more ink flows into the ball from the reservoir to replace what has been used. This happens through the combined effects of gravity and capillary action. The ink flows down towards the ball, and the ball's rotation ensures that fresh ink is always available for writing.

Ball and Socket Mechanism: The key component that makes a ballpoint pen unique is the small ball bearing located at the tip. The ball, usually made of tungsten carbide or stainless steel, acts as a rolling point that transfers the ink onto the paper. The ball is precisely sized to create a slight gap between the ball and the pen's inner wall. As the ball rotates, it picks up the ink from the reservoir and applies it onto the paper. The ball and socket mechanism also ensures that the ink does not leak or dry out when the pen is not in use.



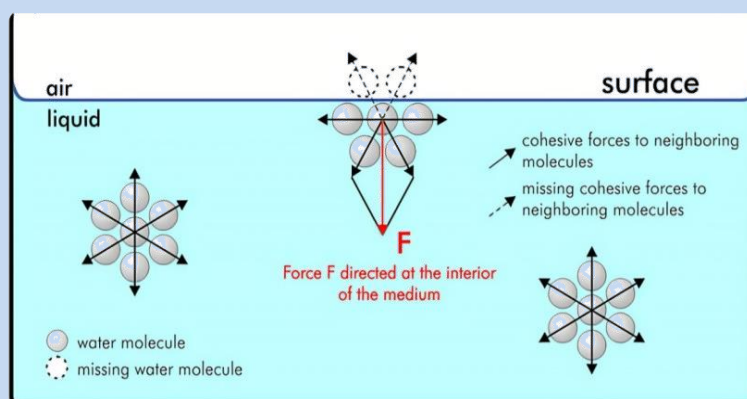
3. Scientific Laws and Principles

a) Principle of Surface Tension: Surface tension is the property of any liquid by virtue of which it tries to minimize its free surface area.

Surface tension not only depends upon the forces of attraction between the particles within the given liquid but also on the forces of attraction of solid, liquid or gas in contact with it.

There are two types of forces adhesive force and cohesive force. The intermolecular force which acts in between the molecules is known as a cohesive force.

Now when a liquid is in contact with a surface then there is an attraction between molecules of the liquid and the surface, these forces adhesive forces.



What Causes Surface Tension?

Intermolecular forces such as Van der Waals force, (a weak force between atoms or molecules.) draws the liquid particles together. Along the surface, the particles are pulled toward the rest of the liquid.

Surface tension is the tendency of the surface of a liquid to shrink into the minimum surface area possible. In other words, it is the ratio of the surface force **F** to the length **L** along which the force acts. Mathematically, surface tension can be expressed as follows:

$$T = \frac{F}{L}$$

Where,

- **F** is the force
- **L** is the length in which force act
- **T** is the surface tension of the liquid

The SI unit of Surface Tension is Newton per Meter or N/m in SI Unit and dyne/cm in CGS Unit .

Surface Tension in Ballpoint Pen acts in the following ways,

- The ink gets spread over the ball due to surface tension.
- The flow of ink to the ball is based on the surface tension. If the surface tension is high, the ink won't spread over the ball properly however if the surface tension is too low, the ink will get spoiled on the paper.

- As the pen moves across the paper, the ball turns and gravity forces the ink down the reservoir and onto the ball where it is transferred onto the paper.

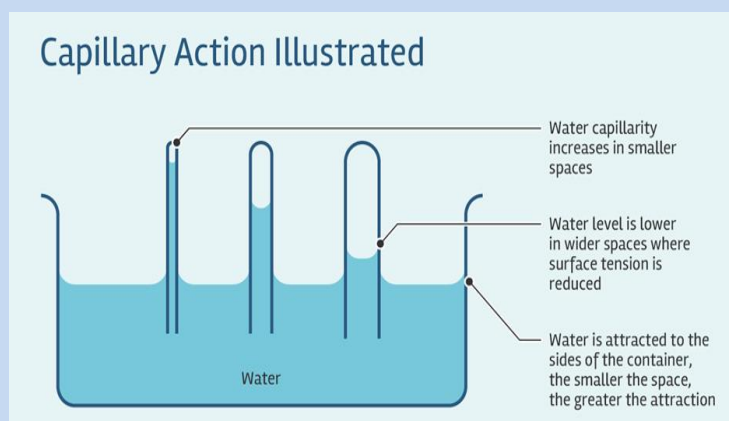
b) Capillary Action

Capillary action is the ability of a liquid to flow in narrow spaces, such as tiny tubes or channels. In a ballpoint pen, capillary action enables the ink to be drawn from the reservoir to the ball at the pen's tip.

The narrow space between the ball and the pen's casing facilitates this capillary action, ensuring a steady supply of ink as the ball rotates.

How Capillary Action on Ball Point Pen take place?

- Capillary action is a liquid's rising action through a tube. This action only draws ink to the tips of pen nibs from a reservoir or cartridge inside the pen.
- The capillary action in a ballpoint pen is a result of the ball's movement, the ink's viscosity, and the combined forces of adhesion, cohesion, and gravity. These factors work together to enable a smooth and controlled flow of ink from the reservoir onto the paper as you write.
- Also, capillary action prevents the ink from leaking out of refill/nib due to gravity.



c) Principle of Viscosity

Viscosity refers to the resistance of a fluid to flow. The ink used in ballpoint pens has a relatively high viscosity, which allows it to flow smoothly onto the paper while also preventing excessive ink leakage. The viscosity of the ink is carefully balanced to ensure controlled ink flow, providing consistent writing.

There are two ways to measure the fluid's viscosity as follows,

- 1) Dynamic Viscosity (Absolute Viscosity)
- 2) Kinematic Viscosity

Dynamic viscosity is the resistance to movement of one layer of a fluid over another. The unit of dynamic viscosity is newton-second per square meter. Usually, it is measured in centipoise (cP). Kinematic viscosity is defined as the diffusivity of momentum. It explains how fast liquid moves when a certain amount of external force is applied. Kinematic viscosity is also expressed as the ratio of fluid dynamic viscosity to its density. The unit of measurement of kinematic viscosity is m^2s^{-1} .



Any two different fluids can have the same dynamic viscosity but will never have the same kinematic viscosity because of the density difference. Here we are discussing the major difference between Kinematic and Dynamic Viscosity.

4. Different Behavior of Ballpoint Pen

a) Why Ballpoint pen smears?

Most quality ballpoint pens are made from oil-based or alcohol-based ink that dries much quicker than other inks, reducing the chances of smearing on the paper. However, if the Surface Tension of the liquid changes due to temperature or the ball in the nib is deformed, chances of smear increase.

b) Reasons Ballpoint Pens Smear

- Abnormal pressure on the nib.
- Poor quality of ink used in the manufacture.
- Hot and Humid conditions causing ink to thin out since the viscosity of liquids decreases rapidly with an increase in temperature.
- Using glossy paper which is less porous paper will take more time to dry up.

c) How to Stop Ballpoint Pens from Smearing

- Clean the tip of your pen.
- Don't store your pen in a hot condition.

d) What Causes a Ballpoint Pen to Leak?

Compared to other types of pens like, e.g., gel pens, fountain pens, ballpoint pens are usually the least prone to ink leaks. However, certain factors can cause the ink to flow more freely.



- Deformed ball due to impact force.
- Deformed nib due to non-uniform force.
- Thermal expansion of nib/ink due to high temperatures. Our normal body temperature is high enough to cause ink molecules to liquefy or expand. When this happens, the ink will move to the tip or the bottom of the pen and leak out. Again, viscosity decreases with increase in temperature.



- Gravity is not on your side when it comes to storing and positioning your ballpoint pens correctly. If you're storing your pens in a vertical position for a long time with the nib facing downwards, you're asking for trouble. Gravity will pull the ink down toward the tip, and the possibility of ink leaking out from the tip is high in cases of poor quality of ink or tip construction.
- When you're flying on a plane, changes in air pressure can cause your ballpoint pen to leak ink. The problem isn't with the pen itself but rather with the air that gets trapped inside the pen's ink cartridge. Liquids like pen ink do not easily expand or compress. When the pressure inside the cartridge equalizes with the surrounding air pressure in the cabin, it causes the air inside the cartridge to expand. When this happens, it can cause the ink inside the cartridge to be pushed out of the cartridge and leak out of the pen.
- Ballpoint Pen Leaking due to surface tension when the pen tip touches a water-absorbent fabric or surface. Ink gets pulled out of the ink cartridge and pen tip and is forced onto the surface it touches.

5. Law and Principles in various tests done on Ballpoint Pen

- Accelerated Ageing:** The accelerated aging test method is based on the theory is that a packaging system in storage exposed to external stress that is more severe than normal environmental stress for a shorter time is equal to the normal stresses the same packaging system experiences in storage over a longer time.
- Flammability Test:** Flammability is the ability of a substance to burn or ignite, causing fire or combustion. Flammability testing can help determine how your products will react when exposed to flames and fire.
- Corrosion Resistance Test:** Corrosion, a natural process that causes the deterioration of materials, is a pervasive and costly problem affecting a wide range of industries. From infrastructure and transportation to manufacturing and electronics, corrosion can compromise the structural integrity and functionality of various materials. However, through the development of corrosion-resistant materials and innovative protective measures, scientists and engineers have made significant strides in mitigating this destructive phenomenon.

- d) **Compression Test on Spring:** Principle behind this test is Hooke's Law, which states that the deformation of an elastic material is directly proportional to the force applied to it, as long as the material remains within its elastic limit.
- e) **Functional Test** This principle encompasses the understanding that a product should be able to withstand repeated use and operate as intended without suffering damage or failure.



- f) **Load Test** Any object has a limit to what force it can bear without deformation or damage. When the ball point pen, fitted with its refill, is pressed against a surface with force exceeding what it can bear, the ball and the cavity in the nib may deform. In this load test, the tip is pressurized for five minutes against a hard surface, such as a glass sheet, with a force of not more than 3 kgf applied gradually at right angles to the axis of the pen while holding the pen between 30 to 40 mm from the ball end and keeping it at an angle of 50° from the horizontal, the pen shall neither break nor its parts get disassembled.

6. Interesting Facts on Ballpoint Pen

- On average, a regular pen can write approximately 45,000 words before it runs out of ink.
- The "Nano fountain Probe" is the smallest pen in the world, and it is utilized by scientists for nanoscale on-chip patterning. The lines it produces are incredibly tiny, measuring only 40 nanometers in width.
- The largest pen in the world was created by Acharya Makunuri Srinivasa in 2011. It holds the Guinness World Record and is fully functional. This ballpoint pen stands at an impressive height of 5.5 meters and weighs 37 kilograms. Despite its colossal size, it also boasts a visually appealing design.
- Biro Company sells 14 million pieces of "BIC Crystal" ballpoint pens daily worldwide. It is the best-selling ballpoint pen in the world.
- The president of the United States signs bills every time with a different pen, which is never used again for signing.
- Parker's ballpoint pens can write a line 8 km long before they run out of ink.
- The ballpoint pen holds a sentimental value for many people. It has been a witness to numerous significant moments, from signing important documents.



7. Questionnaire:

Q1. Which of the following is the most common type of ink used in ballpoint pens?

- a) Oil-based ink
- b) Water-based ink
- c) Gel ink
- d) Dye-based ink

➤ **Answer:** Oil-based ink

Q2. Who is credited with inventing the ballpoint pen?

- a) John Loud
- b) László Bíró
- c) Henry Petroski
- d) Milton Reynolds

➤ **Answer:** László Bíró

Q3. What is the purpose of the ball in a ballpoint pen?

- a) To apply pressure to the paper
- b) To dispense the ink
- c) To create a smooth writing experience
- d) To prevent the ink from leaking

➤ **Answer:** To dispense the ink

Q4. What is the most common size of ballpoint pen?

- a) 0.3 mm
- b) 0.7 mm
- c) 1.5 mm
- d) 2 mm

➤ **Answer:** 0.7 mm

Q5. What is the most common material used to make the barrel of a ballpoint pen?

- a) Plastic
- b) Rubber
- c) Wood
- d) Glass

➤ **Answer:** Plastic



Lesson Plan Subjects

Published

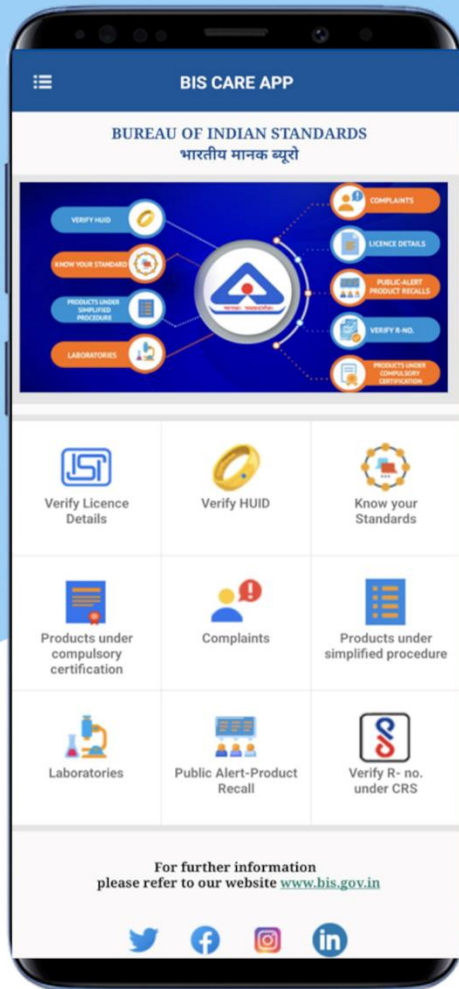
1.	Caustic Soda	16.	Headphones
2.	Football	17.	Milk Powder
3.	Cement	18.	Pressure Cooker
4.	Gas Stove	19.	Plywood
5.	Geyser	20.	Multipurpose dry batteries
6.	Helmet	21.	Ballpoint Pen
7.	LED Bulb	22.	Bicycle
8.	LPG Cylinders	23.	Electric Iron
9.	Cement Ash Brick	24.	Loudspeakers
10.	Paints	25.	Pasteurized Milk
11.	Boric Acid	26.	Paver Blocks
12.	Ceiling Fan	27.	Plugs and Socket
13.	Cables	28.	Solar Flat Plate Collectors
14.	Ceramics Tiles	29.	Precast Concrete
15.	Rear View Mirrors	30.	Stainless Steel

Forthcoming...

31.	Drinking Water	42.	PVC Pipes
32.	Electric Mixer	43.	Refrigerator
33.	Family Sized Biogas Plant	44.	Solid and Hollow Block
34.	Fire Extinguisher	45.	Steel Bar
35.	Power Threshers	46.	Submersible Pump set
36.	Conduits	47.	Thermometer
37.	CNG Cylinders	48.	Tyres for buses and trucks
38.	Hearing Aids	49.	Vacuum Flask
39.	Microwave Oven	50.	Water Meter
40.	Water Storage Tank	51.	Wheel Rim
41.	Weighing balance	52.	Geosynthetics



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