



Learning Science via Standards



Microwave Oven



CM/L-XXXXXXXXXX

Lesson 43
Oct 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.



Microwave Oven

Microwave ovens are popular kitchen appliances that have revolutionized cooking. They utilize a type of electromagnetic wave called microwaves for cooking food. The name "microwave" does not refer to the wavelength being in micro-meter range, but rather to the fact that it is smaller compared to radio waves. These ovens operate at a frequency of around 2.45 GHz, corresponding to a wavelength of 12.23 cm.

Microwave ovens have found widespread application in homes and restaurants due to their efficiency and convenience. They work by emitting microwaves that penetrate food and cause water molecules to vibrate, generating heat and cooking the food quickly. This technology saves time and preserves the natural flavors and nutrients in the food.



The history of microwave ovens dates back to the early 1940s when they were developed for military radar applications during World War II. Their potential for heating food was discovered by accident, leading to the invention of the first microwave oven for household use in 1947. Since then, microwave ovens have undergone significant evolution, becoming smaller, more powerful, and equipped with advanced features to cater to diverse cooking needs.

Today, microwave ovens have become an essential kitchen appliance, offering quick and convenient cooking options for busy households. They have transformed the way we prepare meals, providing a time-saving solution without compromising on taste and quality.

1. How Do Microwave Ovens Work? A Closer Look at the Magic Inside!

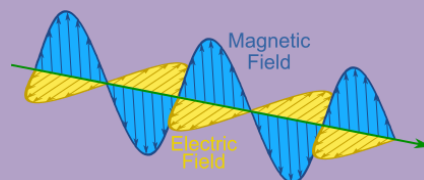
Microwave ovens are truly magical appliances that can cook food in a matter of minutes. But have you ever wondered how they work? Let's uncover the secrets behind their cooking prowess in simple terms.

Microwave ovens work by using microwaves, a type of electromagnetic wave, to heat food. These microwaves are generated by a component called a magnetron and directed into the oven cavity. When the microwaves come into contact with water molecules in the food, they cause the molecules to vibrate rapidly, generating heat. This heat is then transferred to the surrounding food molecules, resulting in quick and efficient cooking.



What is an electromagnetic wave?

Electromagnetic waves are a form of radiation that travels through space. They are a combination of an electric field coupled with a magnetic field.



Microwave ovens are efficient and fast, as they focus on heating the food directly and not wasting energy on heating the oven or surrounding air. They have become an essential kitchen appliance, revolutionizing the way we cook and save time in our busy lives.



2. Why Microwaves? The Science behind Efficient Heating

When it comes to cooking food, why do we rely on microwaves instead of other types of electromagnetic waves? Let's explore the reasons in simple terms.

Visible light and infrared waves may seem like good options, but they are absorbed by the outer layers of food, leaving the inside raw. This would result in a meal with a charred exterior and an uncooked interior. Not ideal!

Radio waves, on the other hand, have long wavelengths, making it challenging to create a powerful and efficient radio oven. While they may provide more even heating, they're not quite suitable for our cooking needs.

X-rays and gamma rays possess high energy levels that can actually alter the chemical bonds in food, potentially creating harmful by products. Definitely not what we want on our plates!

Microwaves have just the right frequency to be absorbed by water molecules, which are present in most foods.



How do microwaves heat the food?

When absorbed, the energy causes the water molecules to heat up and distribute this heat to the surrounding food molecules. This results in thorough and efficient heating of the entire dish.

The key difference between these electromagnetic waves lies in their wavelengths or frequencies, while they all travel at the same speed through a vacuum. So, the next time you enjoy a quick and evenly heated meal from your microwave oven, remember the science behind its impressive cooking capabilities!

3. Microwave VS Conventional Cooking

When it comes to cooking our favorite meals, we have two main contenders: conventional cooking and microwave cooking. But what sets them apart? Let's take a closer look in simple terms.

Conventional Cooking: Heating from the Outside

In traditional cooking methods, heat is applied to the exterior of the food, such as through a flame or a hot surface. The heat then slowly spreads inward through conduction and convection, gradually cooking the entire dish. It's a tried-and-true approach that has been used for centuries.



Convection Oven and Air Fryer





What is conduction and convection?

Conduction is a mode of heat transfer. It is a process of transmission of energy from one particle of the medium to another with the particles being in direct contact with each other.

Convection is a mode of heat transfer where the movement of fluid molecules from higher temperature regions to lower temperature region.

Microwave Cooking: The Power Within

On the other hand, microwave cooking takes a different approach. Instead of applying heat from the outside, it primarily cooks food from within. How? By generating heat directly within the food itself using microwaves. Microwaves are absorbed by food, causing the molecules to vibrate and produce heat that cooks the food.

The Result: Quick and Efficient Cooking

Thanks to this process, microwave cooking is incredibly fast and efficient. It cooks food in a fraction of the time compared to conventional methods. Plus, since the heat is generated within the food, there's less wasted energy and a reduced risk of overcooking or drying out the dish.

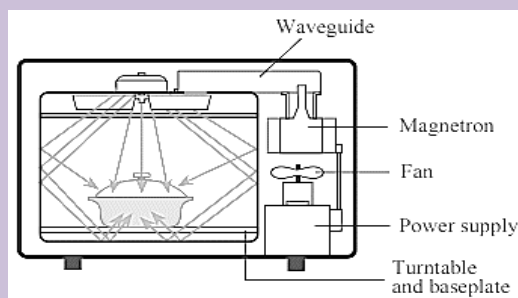
The Versatility of Microwaves

It's worth noting that modern microwave ovens often come equipped with a convection mode, allowing them to function as both microwaves and conventional ovens. This feature expands the cooking options, enabling baking, roasting, and broiling. It's like having two appliances in one!

4. Major Components of a Microwave Oven

Microwave ovens are fascinating appliances with various components that work together to cook our food efficiently. Let's explore the major components, their functions, and the science behind them, keeping in mind the advantages of microwave cooking.

a) Magnetron: The Powerhouse of Microwaves: The magnetron is the heart of a microwave oven. It generates the microwaves used for cooking. Inside the magnetron, electrons are accelerated by a high voltage, creating an oscillating electromagnetic field. This field converts electrical energy into microwaves, which are then directed into the cooking chamber.



How accelerated electrons produce microwaves?

An electron moving with a changing velocity that is, when it is accelerating uniformly, generates a changing magnetic field, produces an electric field which is changing, and this produces a changing magnetic field. An accelerating charged particle hence produces electromagnetic waves of various frequencies.



- b) Waveguide: Guiding the Microwaves:** The waveguide connects the magnetron to the cooking chamber, ensuring the efficient transmission of microwaves. The waveguide is designed to maintain the proper dimensions to match the wavelength of the microwaves. This helps guide the microwaves towards the cooking chamber without loss of energy.
- c) Cooking Chamber: The Space for Culinary Magic:** The cooking chamber is where the food is placed and cooked using microwaves. The chamber is constructed with metallic walls, acting as a Faraday cage. This cage traps the microwaves inside, preventing them from escaping and potentially causing harm. The walls reflect the microwaves to ensure even cooking.
- d) Front Door and Metal Grids: Safety Measures:** The front door, typically made of glass, and the metal grids covering the light bulb cavity serve as safety features. The metal grids on the door and cavity act as a shield against the microwaves. The holes in the grids are smaller than the microwave wavelength, effectively reflecting the microwaves back into the chamber, ensuring they don't escape.
- e) Light Bulb: Illuminating the Culinary Journey:** The light bulb inside the oven cavity illuminates the food, allowing you to monitor its cooking progress. The light bulb produces visible light using electrical energy. This light helps you see inside the oven, making it easier to check on the food without disrupting the cooking process.

Each component of a microwave oven plays a crucial role in creating a safe and efficient cooking environment.



Why metallic materials cannot be used in microwave oven?

Metallic materials cannot be used in microwave ovens for two main reasons:

Reflection: Microwaves are a form of electromagnetic radiation that can be reflected by metal objects. When you place a metal object in a microwave oven, the microwaves are reflected back to the magnetron, which is the device that generates the microwaves. This can damage the magnetron and cause the microwave oven to malfunction.

Sparking: Metal objects can also create sparks in a microwave oven. This can happen when the microwaves are reflected back to the metal object and create a high concentration of energy. The sparks can ignite flammable materials and cause a fire.

5. Safety Measures for Microwave Ovens: Balancing the Cons

While microwave ovens offer numerous advantages, it's important to be aware of their potential drawbacks. Here are some cons to keep in mind, along with safety measures to address them, ensuring user protection.

- a) Limited Capacity: Size Matters:** Many microwave ovens have limited capacity, suitable for small to medium-sized dishes. It's essential to choose a microwave oven that meets your cooking needs, considering the size of dishes you typically prepare. This ensures efficient cooking without overcrowding the oven.

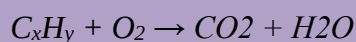


- b) Electrical Shock: *Safety First*:** If the insulation of the microwave oven fails, there is a risk of electrical shock. Manufacturers adhere to safety standards set by organizations like BIS (Bureau of Indian Standards) to ensure proper insulation. Regular maintenance and inspection of the oven can help detect and address any insulation issues promptly.
- c) Radiation Leakage: *Containing the Waves*:** Microwave ovens utilize microwave radiation for cooking, with the potential risk of leakage if the oven is damaged or malfunctioning. Microwave ovens undergo rigorous testing and certification to ensure radiation levels are within safe limits. Regularly checking for any signs of damage or malfunction, such as cracks or gaps, helps prevent radiation leakage.
- d) Interference with Electronic Devices: *Mind the Proximity*:** Microwave ovens may interfere with nearby electronic devices like cell phones and Wi-Fi routers if they are placed too closely. Maintaining a safe distance between the microwave oven and other electronic devices minimizes interference. Follow the manufacturer's guidelines regarding recommended placement and distance from electronic devices.
- e) Risk of Fire: *Handle with Care*:** Overheating food in a microwave oven can potentially lead to a fire. Practicing caution while using the microwave oven is essential. Follow recommended cooking times, avoid using containers or materials unsuitable for microwaving, and never leave the oven unattended while in operation.



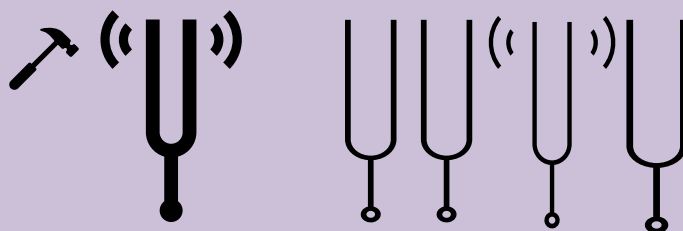
How excessive heating of food can cause fire?

Since food is primarily a hydrocarbon material, it acts as fuel and causes fire in the presence of heat. Hydrocarbons oxidize in the presence of oxygen in the atmosphere producing carbon dioxide and water.



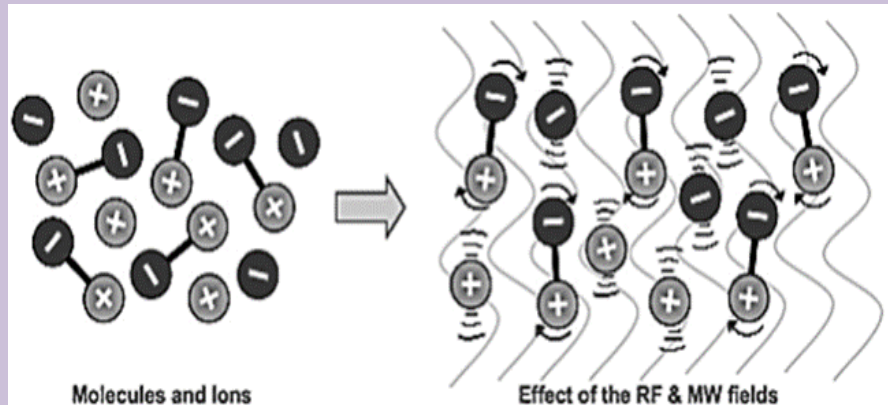
6. Laws, Principles, and Scientific Concepts in Microwave Oven Design and Usage

- a) Resonance:** Resonance is a fundamental principle in physics that describes the tendency of a system to oscillate with greater amplitude at its natural frequency. In the case of microwave ovens, resonance plays a crucial role in the heating process. The microwaves generated by the magnetron are carefully tuned to match the resonant frequency of water molecules present in the food. This matching of frequencies leads to a phenomenon called resonant energy absorption. When the microwaves interact with the water molecules, the oscillations of the molecules become stronger, resulting in rapid heating of the food.

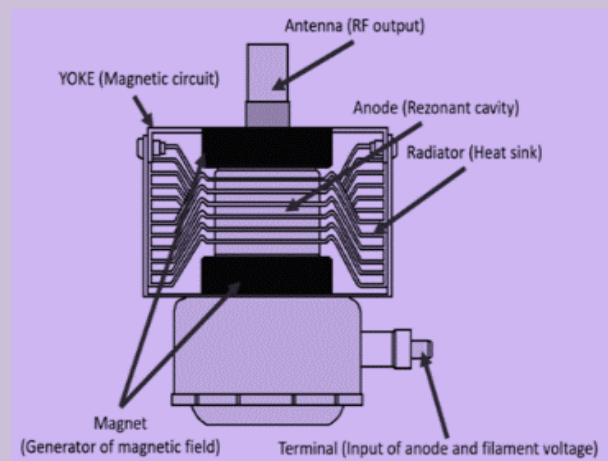


Tuning Fork responding to resonant frequency

- b) **Dielectric Heating:** Dielectric heating is the process by which the temperature of a non-conducting material, such as food, is increased by the application of an alternating electric field. In microwave ovens, the food acts as a dielectric material. When the microwaves penetrate the food, they create an alternating electric field. The electric field causes the polar molecules, like water molecules, in the food to rapidly align themselves with the changing field. This constant reorientation of the molecules generates friction and, consequently, heat. As a result, the food heats up uniformly from within.



- c) **Principle of Generating microwave:** The magnetron is the key component in a microwave oven that generates the microwaves required for cooking. It operates based on the principles of crossed-field devices. Inside the magnetron, electrons are accelerated by a high voltage and guided by magnetic fields into resonant cavities. The interaction between the electric and magnetic fields causes the electrons to spiral around the cavities, emitting microwave radiation in the process. The resonant cavities, with their specific dimensions and magnetic field configurations, determine the frequency and power output of the microwaves.

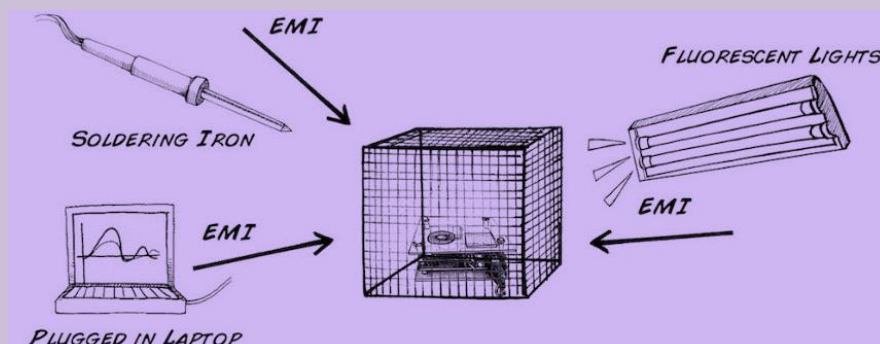


What are various examples of dielectric materials?

Ans. Dielectric materials are materials that do not conduct electricity. They are used in a variety of applications, including capacitors, insulators, and waveguides. There are many different types of dielectric materials, each with its own unique properties.

Porcelain, Mica, Glass, Plastic, Metal oxides, Distilled water, Transformer oil, Dry air, Helium.

d) **Faraday Cage for containing Microwave:** A Faraday cage is an enclosure made of a conductive material, typically metal, that blocks external electromagnetic fields. In a microwave oven, the metallic walls of the cooking chamber act as a Faraday cage. They reflect and contain the microwaves produced by the magnetron, preventing their escape into the surroundings. The Faraday cage design ensures that the microwave energy is directed towards



the food and does not pose a risk to the user.

e) **Double Interlocking Door:** Microwave ovens are equipped with a double interlocking door system for safety purposes. This system ensures that the oven will not operate unless both locks of the door are securely closed. The interlocking mechanism consists of two locks that align and close properly. If either lock is not engaged correctly, the microwave will not turn on, preventing any potential safety hazards. The double interlocking door system is designed to safeguard users from accidental exposure to microwaves during operation.

By incorporating and understanding these laws, principles, and scientific concepts, manufacturers can create microwave ovens that efficiently heat food, contain microwaves safely, and provide reliable and user-friendly operation.

7. Activities

As discussed earlier, microwave oven cook's food by emitting radiations of 2.45GHz i.e., the resonant frequency of water molecules presents in food. It however is important that we understand the concept of resonance through the following activities.

Activities

- What special care should be given if a microwave oven is to be designed to be operated on board ships??
- What care should be taken while designing Door Interlock?
- How can you physically demonstrate the phenomenon of Resonance? Give Examples

Activity # 1: Exploring Vibrations and Sound with a Tuning Fork

Objective: To observe and understand the effects of a vibrating tuning fork on sound and objects.

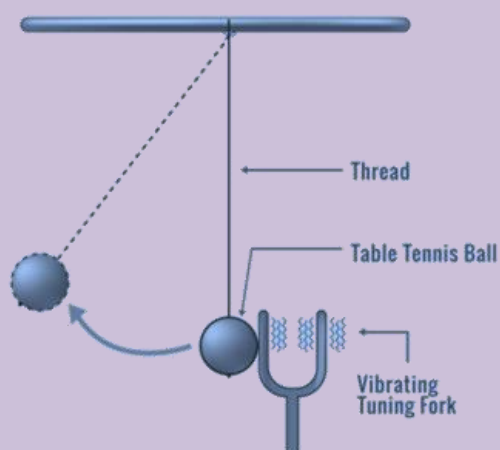
Materials:

- Tuning fork
- Rubber pad
- Table tennis ball or small plastic ball
- Thread
- Support (e.g., a stand or hook)

Procedure:

- Strike one of the prongs of the tuning fork against a rubber pad to set it into vibration.
- Bring the vibrating tuning fork near your ear and observe if you can hear any sound.
- Touch one of the prongs of the vibrating tuning fork with your finger and note your experience.
- Suspend a table tennis ball or small plastic ball from a support using a thread. Ensure it hangs freely.
- Gently touch the ball with the prong of the vibrating tuning fork.
- Observe what happens to the ball and discuss your observations with others.

Vibrating Tuning fork just touching the suspended table Tennis Ball

**Results and Discussion:**

- When the vibrating tuning fork is brought near the ear, you should hear a clear and distinct sound. The tuning fork produces sound waves due to its vibrations, which travel through the air and reach your ear, allowing you to hear the sound.
- When you touch one of the prongs of the vibrating tuning fork with your finger, you may feel a tingling sensation. This occurs because the vibrations of the tuning fork are transferred to your finger upon contact.
- When the prong of the vibrating tuning fork touches the suspended ball, you may notice that the ball starts to vibrate as well. This happens due to the transfer of vibrations from the tuning fork to the ball through the point of contact. The vibrating tuning fork causes the surrounding air molecules to vibrate, creating sound waves that reach the ball and set it into motion.

Conclusion: This activity demonstrates the concept of vibrations and sound. The vibrating tuning fork produces sound waves that can be heard, and its vibrations can be felt when touching it. The transfer of vibrations from the tuning fork to the suspended ball showcases how vibrations can be transmitted from one object to another. It provides a hands-on experience to understand the relationship between vibrations, sound, and the effects they have on objects.

8. How Green Is It... To Use A Microwave?

Microwave ovens offer several sustainability benefits and can contribute to eco-friendly practices in various ways:



- a) **Energy Efficiency:** Microwave ovens are highly energy-efficient compared to conventional ovens and stovetops. They utilize electromagnetic waves to directly heat the food, reducing energy wastage by eliminating the need for preheating or heating the surrounding air.
- b) **Reduced Cooking Time:** The quick cooking time of microwave ovens helps conserve energy by significantly reducing the amount of time required to prepare meals. This can lead to lower overall energy consumption in the kitchen.
- c) **Waste Reduction:** Microwave ovens allow for precise cooking, preventing overcooking or overheating of food. This reduces food waste, as it helps retain the nutritional value, texture, and taste of the food.
- d) **Preservation of Nutrients:** Microwaving is known to preserve more nutrients in food compared to other cooking methods. By minimizing nutrient loss during cooking, microwave ovens contribute to healthier and more sustainable food consumption.
- e) **Resource Conservation:** Microwave ovens often require less water for cooking compared to traditional methods like boiling or steaming. This helps conserve water resources, especially in regions facing water scarcity.
- f) **Alternative Cooking Methods:** Microwave ovens offer versatile cooking options beyond heating and defrosting. They can be used for steaming, cooking vegetables, and preparing small meals. By utilizing these functions, users can reduce their reliance on energy-intensive cooking appliances.
- g) **Reduced Carbon Footprint:** The energy-efficient nature of microwave ovens leads to a lower carbon footprint. By minimizing energy consumption during cooking, microwave ovens contribute to the reduction of greenhouse gas emissions associated with energy production.

To maximize the sustainability benefits of microwave ovens, it is essential to use them responsibly and consider eco-friendly practices such as using microwave-safe, reusable containers, avoiding excessive packaging, and choosing locally sourced, seasonal ingredients. By incorporating sustainable cooking habits, individuals can optimize the environmental advantages offered by microwave ovens.



9. Interesting facts about Microwave Ovens

- a) **Invention by Accident:** The microwave oven was invented by Percy Spencer in 1945 when he noticed a candy bar in his pocket melted due to microwaves emitted from a magnetron.
- b) **Faster Than Traditional Cooking:** Microwave ovens can cook food much faster than conventional methods. They can heat food up to three times faster than a conventional oven, making them a time-saving appliance.
- c) **Microwave Ovens and Wi-Fi:** Microwave ovens can interfere with Wi-Fi signals when they operate on the same frequency range (2.4 GHz). It is recommended to keep a distance between the microwave oven and Wi-Fi routers for optimal Wi-Fi performance.
- d) **Popcorn and Microwaves:** Microwave ovens are well-known for their ability to quickly pop popcorn kernels. The microwaves excite the moisture within the kernels, causing them to heat up and pop.
- e) **No Metal in Microwaves:** Metal objects should not be placed inside a microwave oven as they can cause sparks and even damage the appliance. Microwaves cannot penetrate metal, causing the energy to reflect and potentially cause a fire hazard.
- f) **Microwaves Can Sterilize:** Microwave ovens can be used to sterilize kitchen sponges and other small, non-metallic objects. The heat generated by the microwaves can help eliminate bacteria and germs.
- g) **Not All Containers Are Microwave-Safe:** Not all containers are suitable for microwave use. Certain materials, such as metal, aluminium foil, and some plastics, can melt, warp, or release harmful chemicals when exposed to microwaves. It is important to use microwave-safe containers and follow the manufacturer's instructions.
- h) **Microwaves and Radiation:** While microwave ovens use radiation to cook food, they do not emit harmful levels of radiation when used correctly. Microwaves are designed to contain the radiation within the oven, and safety regulations ensure that the emitted levels are within safe limits for human health.



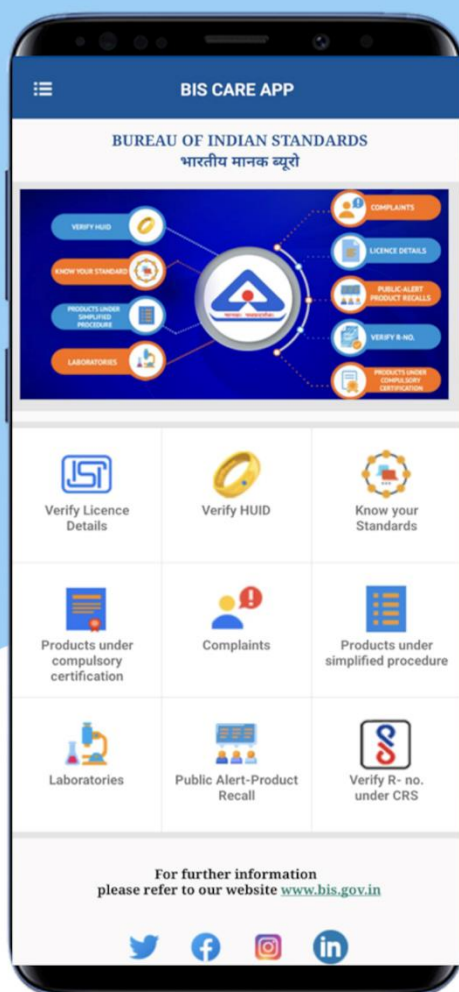
Lesson Plan Subjects

Published

1.	Caustic Soda	27.	Plugs and Socket
2.	Football	28.	Solar Flat Plate Collectors
3.	Cement	29.	Precast Concrete
4.	Gas Stove	30.	Stainless Steel
5.	Geyser	31.	Weighing balance
6.	Helmet	32.	Steel Bar
7.	LED Bulb	33.	Thermometer
8.	LPG Cylinders	34.	Tyres for buses and trucks
9.	Cement Ash Brick	35.	Vacuum Flask
10.	Paints	36.	Water Meter
11.	Boric Acid	37.	Wheel Rim
12.	Ceiling Fan	38.	Water Storage Tank
13.	Cables	39.	PVC Pipes
14.	Ceramics Tiles	40.	Refrigerator
15.	Rear View Mirrors	41.	CNG Cylinders
16.	Headphones	42.	Hearing Aids
17.	Milk Powder	43.	Microwave Oven
18.	Pressure Cooker	44.	Solid and Hollow Block
19.	Plywood	45.	Submersible Pump set
20.	Multipurpose dry batteries	46.	Conduits
21.	Ballpoint Pen	47.	Drinking Water
22.	Bicycle	48.	Electric Mixer
23.	Electric Iron	49.	Family Sized Biogas Plant
24.	Loudspeakers	50.	Fire Extinguisher
25.	Pasteurized Milk	51.	Power Threshers
26.	Paver Blocks	52.	Geosynthetics



BIS CARE APP



*A tool
for
Consumer Empowerment*

Scan to Download



Features

- Check the authenticity of the Product with  mark by using 'Verify Licence Details'
- Check the authenticity of Hallmarked Jewellery item with HUID number  by using 'Verify HUID'
- Select 'Know your Standards' for information on any indian standard, Licenses against it and laboratories for this product.
- Get locations of BIS labs and Offices.
- Check the authenticity of electronic products with R-Number  by using 'Verify R-Number under CRS'
- Register complaints regarding quality of Product of misuse of  mark by using 'Complaints'
- You can also access products under compulsory certification of BIS & Products under simplified procedure of licensing.

How to use BIS Care App

- Go to Google play store/Apple app store
- Install BIS Care App
- Register your mobile number



BUREAU OF INDIAN STANDARDS
(THINK, NUDGE, & MOVE DEPARTMENT)

Manak Bhavan,
9, Bahadur Shah Zafar Marg,
New Delhi – 110002.

Follow us on Social Media
Website <https://www.bis.gov.in>



twitter.com/IndianStandards



facebook.com/IndianStandards



instagram.com/indianstandards