BUREAU OF INDIAN STANDARDS

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Learning Science via Standards

Fire Extinguisher

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Lesson 48

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STANDARDS CLUB
BUREAU OF INDIAN STANDARDS

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.

Portable Fire Extinguisher

In the face of a fire emergency, the ability to extinguish flames quickly and effectively is of utmost importance. This is where portable fire extinguishers come to the rescue. These compact devices are designed to combat small fires before they can escalate into life-threatening blazes.

Portable fire extinguishers find their application in various situations, including homes, offices, schools, and public spaces. They provide a first line of defence, enabling individuals to respond swiftly to fires and prevent their spread, potentially saving lives and property.

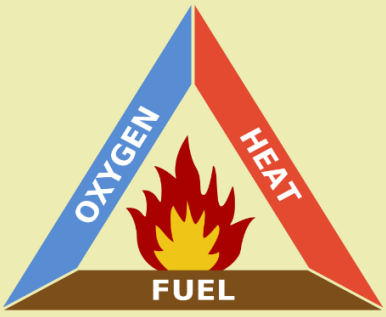
The concept of fire extinguishment dates back centuries. In ancient times, rudimentary extinguishing methods involved using water or sand. However, the modern portable fire extinguisher as we know it today emerged in the early 19th century. Notable advancements included the development of the soda-acid extinguisher and the carbon tetrachloride extinguisher.

Over time, fire extinguisher designs improved, introducing safer and more effective extinguishing agents such as dry chemical powders, foam, and carbon dioxide. Today, portable fire extinguishers are available in various types, sizes, and classifications, each suitable for specific fire hazards.

1. Understanding Fire: The Elements and Chemical Reactions

Fire is a chemical reaction that occurs when fuel, oxygen, and heat come together. These three elements form the fire triangle, which is essential for a fire to burn. Let's delve into the components of fire and how they interact.

a) **The Fire Triangle:** The fire triangle consists of fuel, oxygen, and heat. All three elements must be present simultaneously for a fire to occur.



i) **Fuel:** It can be in the form of solids, liquids, or gases. During combustion, the fuel is heated, releasing gases that react with oxygen.

ii) **Oxygen**: Usually obtained from the air, oxygen is necessary for combustion. It combines with the gases released by the fuel during the chemical reaction.

iii) **Heat**: Heat is the energy that initiates and sustains the fire. It raises the temperature of the fuel, allowing the chemical reaction to occur.

What is combustion?

When the fuel is heated, it releases gases. Gases undergo combustion. These gases, when hot enough, break apart into fragments, which then combine with oxygen to form new molecules. The primary products of combustion are water molecules (H_2O) and carbon dioxide molecules (CO_2), though other by products can form if the burning process is incomplete.

b) **Sustaining the Fire:** The heat generated by the chemical reaction sustains the fire. The flame keeps the remaining fuel at its ignition temperature, allowing the fire to continue spreading. As long as there is enough fuel and oxygen, the fire will keep burning, releasing combustion products and heat energy.

Fuel + Oxygen (air) = Combustion Products (mainly CO_2 + H_2O) + Heat Energy

Understanding the fire triangle and the chemical reactions involved in combustion provides insight into the nature of fire. Remember, controlling any one element in the fire triangle can help prevent or extinguish a fire, ensuring the safety of people and property.

How heat is generated by a chemical reaction?

During a chemical reaction, bonds are broken and new bonds are formed. Breaking chemical bonds is endothermic, a process that requires an input of energy or absorption of heat. The reverse process of bond breaking is bond formation, which is exothermic, meaning it releases energy or gives off heat.

Heat generated by a chemical reaction can determined by summation of all the bond energies formed or broken in the reaction process.

2. Types of Fire

Fires are classified according to the type of fuel that is burning, which is as under:

Class A - Fires involving solid combustible materials of organic nature such as wood, paper, rubber, plastics, etc., where the cooling effect of water is essential to extinguish the fire.

Class B - Fires involving flammable liquids or liquefiable solids or the like where a blanketing effect is essential to extinguish the fire.

Class C - Fires involving flammable gases under pressure including liquefied gases, where it is necessary to inhibit the burning gas at fast rate with an inert gas, powder or vaporizing liquid for extinguishment.

Class D - Fires involving combustible metals such as magnesium, aluminium, zinc, sodium, potassium etc. The burning metals are reactive to water. The most common method for extinguishing a combustible metal fire is to cover the burning material with a dry powder, such as sand, which will not react with the material containing agents.

Class F - Fires involving cooking media (vegetable or animal oils and fats) in cooking appliances and may be called kitchen fire.

It is important to understand the Classification of fires as the same extinguishing medium cannot be used for all types of fires. Each Class of fire can be extinguished by specific extinguishing medium to that classification alone. The fire extinguishers are marked with the Class of fire for which they can be used.

3. Principle of Extinguishing Fire

The principle of extinguishing fire says that removing one or more of the three elements can put out a fire. There are three different approaches on doing so.

a) **Cooling:** One of the most widely known and effective approaches in extinguishing fire is removing the heat. Thus, cooling with water is one of the most popular methods. The heat generated by the fire is absorbed by the water.

b) **Starving:** Starving the fire from its fuel source is a different approach. When fire runs out of flammable materials, it will eventually burn out itself.

c) **Smothering:** The third approach involves the last element in the triangle, oxygen. Smothering is a technique where oxygen is removed. This approach is commonly applied to solid fuel fires.

Can we use water for extinguishing fire due to electrical short circuit?

Water is a good conductor of electricity. When you pour water on an electrical fire, it can create a pathway for the electrical current to flow, potentially leading to electrical shock or further ignition of the fire. This can put the person attempting to put out the fire at risk.

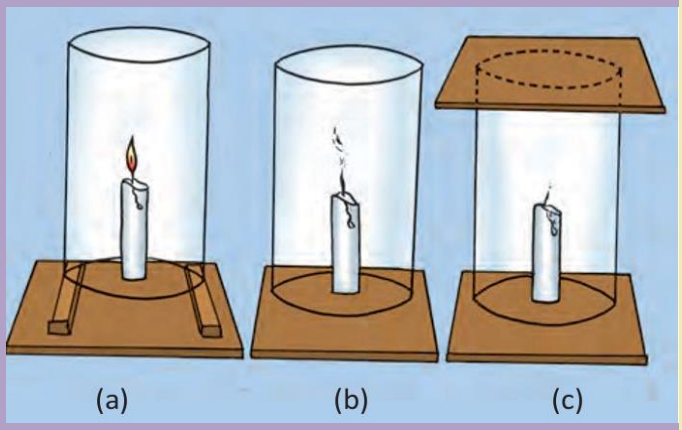
Also, when water comes into contact with live electrical equipment or wires, it can undergo electrolysis, a chemical process that breaks water into its component gases, hydrogen and oxygen. This can lead to the release of flammable gases, increasing the risk of an explosion.

ACTIVITY#1: Experiment to understand oxygen is essential for burning

Fix a lighted candle on a table. Put a glass chimney over the candle and rest it on a few wooden blocks in such a way that air can enter the chimney [See image (a)] Observe what happens to the flame.

Now remove the blocks and let the chimney rest on the table [See image (b)]. Again, observe the flame.

Finally, put a glass plate over the chimney [See image (c)]. Watch the flame again.



What happens in the three cases? Does the flame flicker off? Does it flicker and give smoke? Does it burn unaffected? Can you infer anything at all about the role played by air in the process of burning?

4. How Fire Extinguishers work?

A fire extinguisher is an external fire safety system useful to extinguish or control minor fires, often in emergency cases. Usually, a fire extinguisher consists of a hand-held cylindrical pressure vessel carrying an agent which discharges to extinguish the fire. Fire extinguishers work by removing the access of fire to oxygen by blanketing the fire using a layer of extinguishing media.

It is necessary for the media not to be flammable themselves. Fire can also be extinguished by removing the fuel from the fire.

5. Types of Portable Fire Extinguishers

Portable fire extinguishers are not expected to deal with large fires but, these are very valuable if used promptly and efficiently in the early stages of fire. Extinguishers are labelled with either letter-shaped or pictorial symbols that indicate what types of fires the extinguisher is designed for.

Fire Extinguishers may be classified by the type of extinguishing medium,

a) Water based: Water Based Fire extinguishers extinguish fire by taking away the "heat" element of the Fire Triangle.

✶ *Extinguishing Media – Water and Water Mist*

b) Foam based: They spray a type of foam (mixed with water) that expands when it hits the air and blankets the fire. This blanket prevents the vapours from rising off the liquid to feed the fire, thus starving it of fuel. Also, because the foam is mixed with water, it has a cooling effect as well.

✶ *Extinguishing Media– Foam (Mixed with water)*

c) Powders — ABC/BC/D Type: The greatest portion of this powder is composed of Mono Ammonium Phosphate (MAP) and the extinguishers are pressurized with nitrogen. Dry chemical extinguishers put out fire by coating the fuel with a thin layer of dust. This separates the fuel from the oxygen in the air. The powder also works to interrupt the chemical reaction of fire.

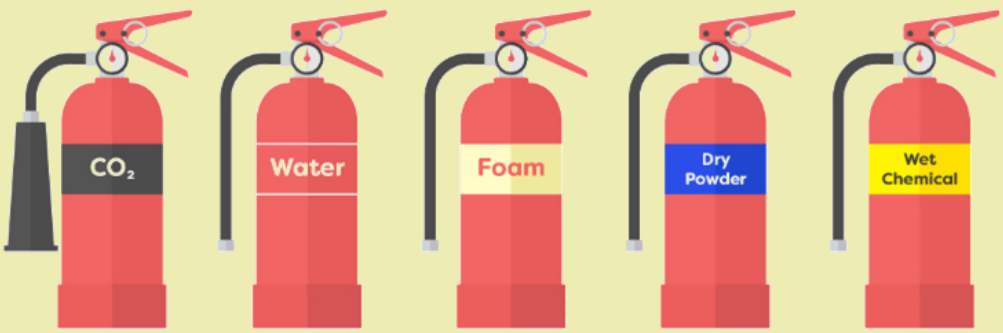
✶ *Extinguishing Media–Dry Chemical Powder*

d) Carbon dioxide Type: Carbon dioxide is a non-flammable gas that takes away the oxygen element of the fire triangle. Without oxygen, there is no fire. Carbon dioxide is very cold as it comes out of the extinguisher, so it cools the fuel as well.

✶ *Extinguishing Media–* Carbon Dioxide(CO_2), a non-flammable gas

e) Wet chemical Type: These extinguishers contain a solution composed of Potassium that effectively launches a two-pronged assault on fires. Due to the chemical reaction of the solution with the cooking medium, a thick soap-like substance forms, sealing the surface of the liquid to prevent re-ignition.

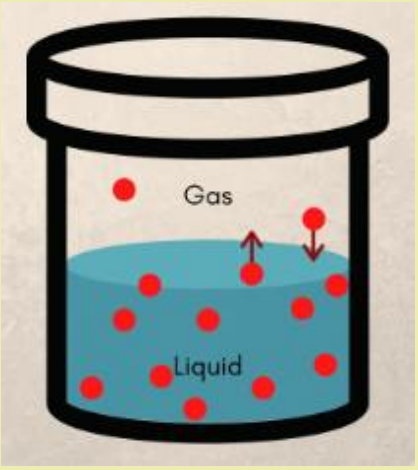
✶ *Extinguishing Media– Chemical like Potassium.*



6. Scientific Principles Involved in Operation of Fire Extinguisher

a) Principle of Equilibrium Pressure

A liquid in a closed space is in equilibrium with its gaseous phase, which means the number of molecules in liquid phase and gaseous phase stay constant. The pressure exerted by the gaseous phase in such equilibrium is known as equilibrium pressure.



When ambient temperature increases, the number of molecules in gaseous phase increases, thereby increasing the equilibrium pressure.

Similarly, when ambient temperature decreases, the molecules in liquid phase increase, thereby decreasing the equilibrium pressure.

The service charge of an extinguisher, i.e., the equilibrium pressure inside a normally charged and pressurized extinguisher kept at 27 ± 5 °C and operating temperatures of extinguisher are designed on the principle of temperature-pressure correlation and equilibrium pressure.

b) Chemical Reaction

Atoms, the tiniest building blocks of matter, rearrange themselves during the chemical reactions, leading to new compounds with low energy and different properties. From the rusting of iron to the sizzling of a frying pan, chemical reactions are everywhere. They release energy, like in fireworks, or absorb it, like when ice melts. Understanding chemical reactions helps us make medicines, cook delicious meals, and even power our cars. Certain types of fire extinguishers utilize chemical reactions to inhibit the fire's progress. For instance, dry chemical extinguishers contain substances like monoammonium phosphate or sodium bicarbonate that chemically react with the fire to form a barrier of water and carbon dioxide, interrupting the fire's access to fuel or oxygen.

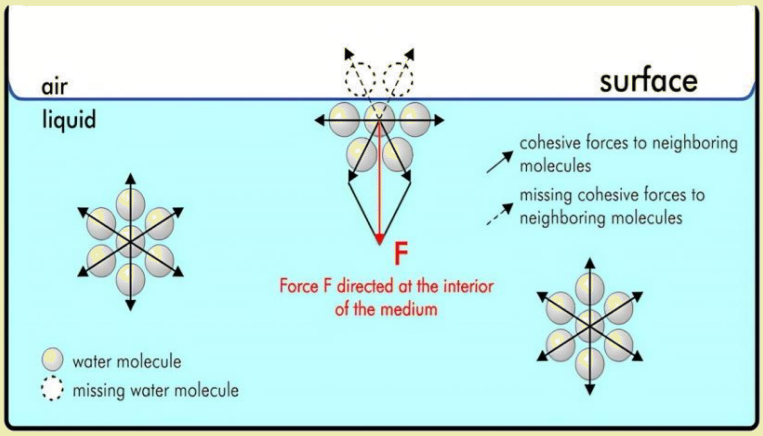
Is the principle of corrosion applicable in the case of fire extinguishers?

Yes, Fire extinguisher stores extinguishing media in metal containers in cylindrical share which are prone to process of corrosion. Corrosion is a natural process where materials made from metal deteriorate through an electrochemical reaction known as oxidation (rusting). Corrosion occurs due to reaction of oxygen available in atmosphere in the presence of water molecules (humidity) with metals like Iron, Copper, etc. Fire extinguishers are protected by providing protective layers of coating such as galvanization, paints etc..

DO YOU KNOW?

Electrochemical Reaction - Atoms contains electrons in their shells which carry negative charge. The mobilization of these electrons produces electricity. Electrochemical reaction is a process that consists of elements (basically metals) reacting to give electrons that conduct electric current and generate electrical energy. Thus the electrochemical process is the conversion of chemical reactions into electric energy.

c) Concept 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 are known as adhesive forces.

Also, Intermolecular forces such as **Vander Waals Force,** (a distance-dependent interaction 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 defined as, the ratio of the surface force **F** to the length **L** along which the force acts.

How surface tension is useful in fire extinguishers?

Fire extinguishers that utilize foams or other surface-active agents which are used to extinguish fires on liquids like oils on water etc., work on the principle of reducing the surface tension of water. This enables the foam to spread over the fuel, cutting off the oxygen supply and smothering the fire.

d) Principle of Fluid Dynamics & Conservation of Mass in Fire Extinguisher

The discharge rate and duration of a fire extinguisher are related to the scientific principles of fluid dynamics and the conservation of mass.

Fluid dynamics is the study of how fluids (liquids and gases) behave and interact with their surroundings.

In the case of a fire extinguisher, the extinguishing agent (such as water, foam, dry chemical, or carbon dioxide) is stored under pressure in the extinguisher's container. When the extinguisher's valve is opened, the pressure inside forces the agent out in a controlled manner. The conservation of mass principle states that mass cannot be created or destroyed in an isolated system.

When a fire extinguisher is activated, the extinguishing agent is expelled from the container at a specific rate, determined by the size and design of the discharge nozzle and the pressure inside the

extinguisher. The mass flow rate (mass of agent expelled per unit of time) remains constant as long as the pressure is sufficient and the nozzle remains unobstructed.

The duration of the fire extinguisher's discharge depends on the amount of extinguishing agent stored inside the container and the discharge rate. It's essential to balance these factors to ensure the extinguisher can effectively control and suppress the fire without running out of agent too quickly.

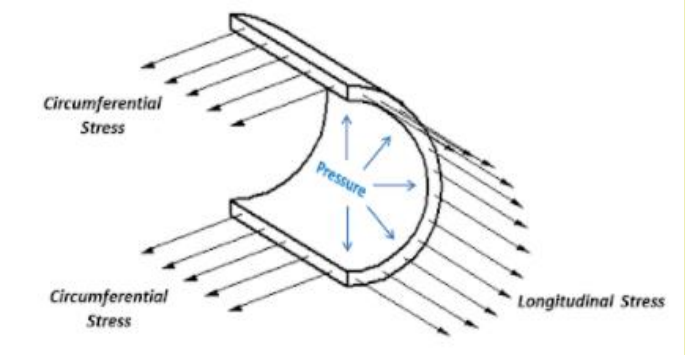
Can you identify some more applications of fluid dynamics?

Fluid dynamics is a common study in applications like Aircrafts, High Speed Trains, Wind Turbines, High Speed Blowers, Steam Turbines etc.

e) Concept of Hoop Stress in Fire Extinguisher

Hoop stress is a type of stress that occurs in a cylindrical or tubular structure, such as pipes, tubes, or pressure vessels, when they are subjected to internal pressure. It is a circumferential stress that acts perpendicular to the longitudinal axis of the cylinder.

When pressure is applied inside a cylindrical structure, the material's cross-section tends to expand outward. Hoop stress develops in response to this outward expansion and is responsible for trying to prevent the cylinder from bursting or failing due to the internal pressure.



Pascal's law says that pressure applied to an enclosed fluid will be transmitted without a change in magnitude to every point of the fluid and the walls of the container. The pressure at any point in the fluid is equal in all directions

Hoop stress can be calculated using the formula:

$$\sigma_h = \frac{P\ x\ R}{t}$$

Where:

σ_h is the hoop stress, P is the internal pressure

R is the radius of the cylinder, and 't' is the thickness of the cylinder's wall

Why cylindrical shaped containers are commonly used for storage of gasses?

Gases are commonly stored at high pressure to save and accommodate for storage space. Also, we learned from pascal's law that fluids exert uniform pressure on all sides. Cylindrically shaped containers distribute these stresses developed by the gasses uniformly across the cross section thereby avoiding any stress concentrations on the container. Any uneven stress would lead to deformation of the walls of the container in which high pressure fluids are stored.

The hoop stress is directly proportional to the internal pressure and the radius of the cylinder, while inversely proportional to the thickness of the cylinder's wall. Engineers and designers consider hoop stress when designing cylindrical structures to ensure they can safely withstand the anticipated internal pressure without failure or rupture. Proper material selection, adequate thickness, and appropriate manufacturing techniques are crucial in ensuring the structural integrity and safety of cylindrical components under pressure.

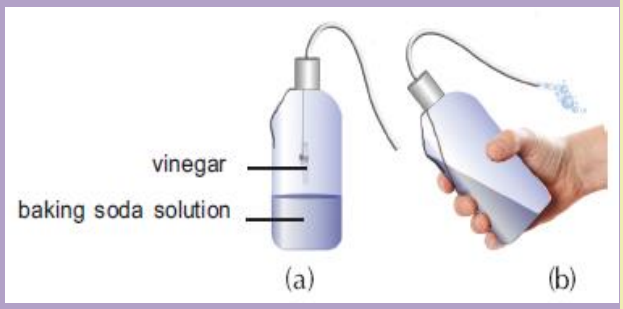
The cylinder hydro burst test is designed to test the highest pressure reached during the bursting of a cylinder under internal Hydrostatic Pressure. The test usually uses water as the pressurizing medium and gradually increases the pressure of the cylinder under test until burst occurs at weakest point due to both Longitudinal and Circumferential Stress (Hoop Stress).

Bursting of the Cylinder occurs if the force created by the internal pressure exceeds the hoop stress's resisting force.

Activity# 2:

Experiment to understand carbon dioxide is non-supporter of combustion.

Arrange the apparatus as shown below. Add the vinegar contained in the test tube to the sodium bicarbonate (baking soda) solution by tilting the wash bottle. Introduce the resultant gas to a candle flame. Record your observation. What is your inference?



When vinegar will react with baking soda solution then CO2 gas will evolve because acetic acid is present in vinegar and when this gas will pass to candle flame then this gas will put out the candle flame. So, from this it is clear that CO2 gas is non-supporter of combustion.

7. Suitability of Different Types of Fire Extinguishers

Type (Fire / Extinguisher)	CLASS A Combustible materials (e.g. paper & wood)	CLASS B Flammable liquids (e.g. paint & petrol)	CLASS C Flammable gases (e.g. butane and methane)	CLASS D Flammable metals (e.g. lithium & potassium)	Electrical Electrical equipment (e.g. computers & generators)	CLASS F Deep fat fryers (e.g. chip pans)	Comments
Water	✓	✗	✗	✗	✗	✗	Do not use on liquid or electric fires
Foam	✓	✓	✗	✗	✗	✗	Not suited to domestic use
Dry Powder	✓	✓	✓	✓	✓	✗	Can be used safely up to 1000 volts
CO2	✗	✓	✗	✗	✓	✗	Safe on both high and low voltage
Wet Chemical	✓	✗	✗	✗	✗	✓	Use on extremely high temperatures

Fire Class	Material on Fire i.e. Fuel	Suitable type of Fire Extinguisher
Class A	Ordinary combustible solids such as wood, paper, rubber, plastics, furniture, curtains etc.	water, foam, ABC dry chemical powder and halo carbons extinguishers
Class B	Flammable liquids or liquefiable solids such as petrol, diesel oil, acetone, wax etc.	Foam, dry chemical powder, clean Agents and carbon dioxide (CO2) extinguishers
Class C	Flammable gases under pressure including liquefied gases such as LPG, natural gas, propane, methane etc.	Dry chemical powder, clean Agents, and carbon dioxide (CO2) extinguishers
Class D	Combustible metals such as magnesium, aluminium, zinc, sodium, potassium, etc.	Extinguishers with special dry powder suitable for metal fires
Class F (Kitchen Fire)	Cooking media such vegetable or animal oils and fats etc.	Wet chemical fire extinguisher

Is the Sun a ball of fire and does it need oxygen to burn?

Sun is a huge sphere of gases like hydrogen and helium. Sun does not need oxygen to burn, rather it is a process of nuclear fusion reaction. Nuclear fusion is the process of fusion of two or more nuclei of an atom to form a heavier nucleus. This nuclear fusion produce enormous temperatures which turn gases into plasma and emit light.

8. Interesting Facts about Fire Extinguishers

a) **Ancient Origins:** While modern portable fire extinguishers have evolved over time, the concept of fire extinguishment dates back thousands of years. The ancient Greeks and Romans used hand-operated devices to extinguish fires, employing methods such as using water pumps and chemical solutions.

b) **First Fire Extinguisher Patent:** The first recorded patent for a portable fire extinguisher was issued in 1723 to Ambrose Godfrey of England. His invention involved a fire-extinguishing device that used a pewter container filled with a liquid mixture of water and potassium carbonate.

c) **Fire Extinguisher Ratings:** Fire extinguishers are labelled with ratings that indicate their effectiveness against different fire classes. The ratings consist of a number and a letter. The number represents the extinguisher's relative firefighting capability, while the letter denotes the class of fire it is suitable for.

d) **PASS Technique:** To operate a portable fire extinguisher effectively, the PASS technique is commonly taught. PASS stands for Pull the pin, Aim at the base of the fire, Squeeze the handle, and Sweep from side to side. Following this technique ensures proper deployment of the extinguishing agent.

e) **Fire Tetrahedron:** The fire tetrahedron is an expanded version of the fire triangle, incorporating a fourth element: the chemical reaction. In addition to fuel, oxygen, and heat, a chemical chain reaction is required to sustain a fire. Understanding this concept helps in designing effective fire extinguishing agents.

f) **CO_2 Extinguishers and Electrical Fires:** Carbon dioxide (CO_2) fire extinguishers are commonly used for electrical fires because they do not leave behind any residue that could damage electrical equipment. CO_2 displaces oxygen, suffocating the fire, and preventing it from spreading.

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

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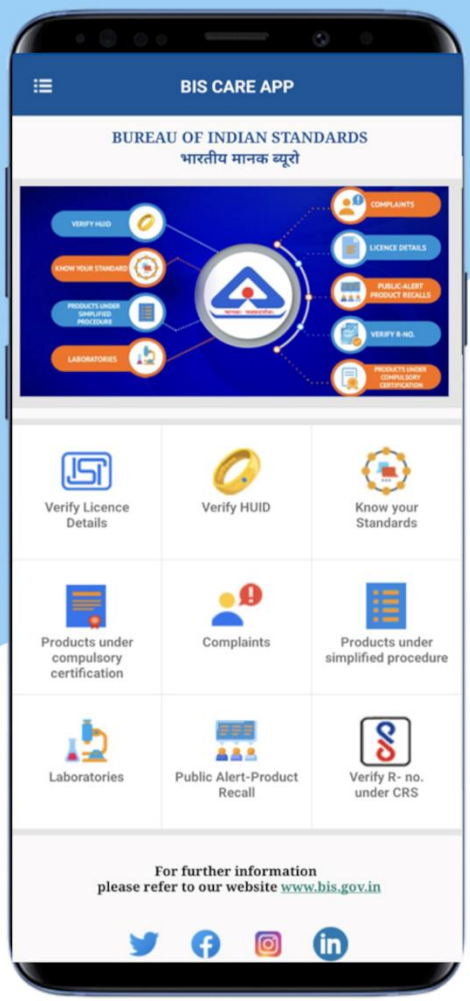

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