LU 8.6. Twists in the fibres

Overview

This unit is about understanding fibres as materials. The techniques described here are used by many textile experts throughout the world to identify the fibres that a fabric is composed of. The ideas that have emerged from the use of such techniques have led further to the development of modern materials based on new polymers and mixed polymers. This unit explores how various fibres – plant fibre (cotton), animal fibre (wool or silk), and synthetic fibre (polyester) look under the microscope. It also explores the burning properties of various fibres. It discusses how the diversity of properties makes specific fibres useful in specific contexts and makes them important to the livelihoods of numerous craftspersons and practitioners.

Minimum time required: 4 sessions of 40 min each.

Type of unit: Laboratory

Unit-specific objectives

(i) To identify materials by macroscopic characteristics and correlate them with microscopic or chemical characteristics.

(ii) To identify fibres through controlled use of combustion (this test can be extended to other materials as well with suitable modifications in design).

(iii) To learn to use a microscope to observe fibres.

(iv) To relate ash to metal oxides and silica, and oxidation of non-metals to gaseous products

(v) To observe (qualitative) microscopic and chemical differences between fibres.

Links to curriculum

The topic of fibres runs in NCERT science text books from Classes 6 to 8, with plant-based fibres discussed in Class 6, animal-based in Class 7, and synthetic fibres in Class 8. The burning test has been suggested as an activity in Class 6 science textbook (Chapter: From Fibre to Fabric). This Learning Unit connects to these and other topics in Class 8 science textbook (Metals and Non-metals, Combustion and Flame).

Introduction

Has anybody in your family bought silk or wool and found later that it was not pure silk or wool? Although we use bags, ropes, clothes, and items made from different fabrics, it is difficult to ascertain the purity of the fabric by touch, texture, or weight alone. A fibre or yarn may look like cotton but it may be synthetic. One cannot trust appearance alone.

Would you like to learn simple ways to identify fibres? In this Learning Unit, you can explore this through two techniques: burning test and microscopy.

Did you know?

A thread is not a fibre but a bundle of fibres. You can see this in figure 1.

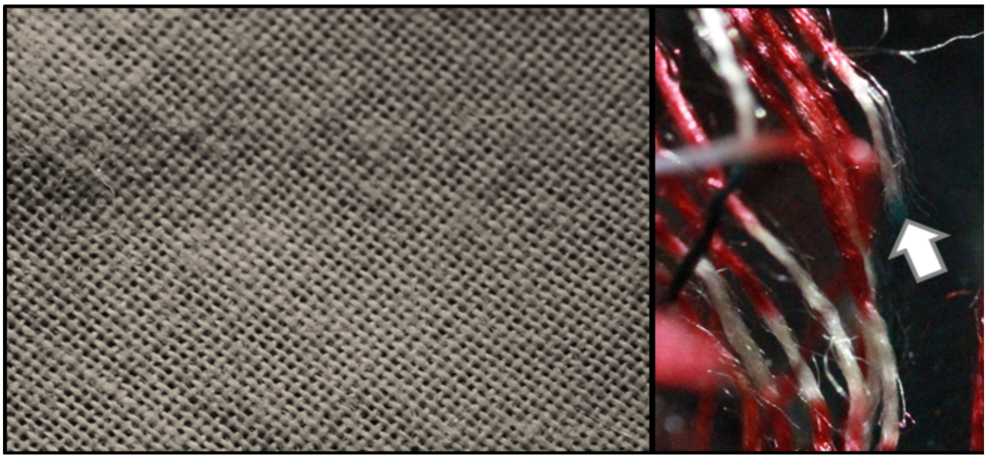

Figure 1: *(Left) A cloth is made of threads. (Right) Each thread is made of several fibres (indicated by arrow).*

Materials required

- Threads: cotton, polyester (or any other synthetic thread), wool (if you don't get real wool, a broken hair can also be used), and a thread made of unknown fibre. The fibres should be clean, so that any other substance sticking to them does not affect the observations.
- Candle, match stick, beaker, forceps, watch glass, water, tray.
- Microscope, glass slide, and cover slip.

Burning test for fibres

There is a popular saying in Hindi "*Rassi jal gai, par bal nahin gaye*.", meaning "the rope got burnt, but the twists in the rope have remained (in the form of ash)". This is a property of ropes that are made of plant fibres, which on burning produce ash in which twists can still be seen. Figuratively, it also refers to someone's personality traits that did not change even after facing a lot of difficulties in life.

Textile experts across the world have been using burning tests to identify fibres. Plant fibres burn slowly producing ash, which glows for few seconds (known as afterglow) before cooling down. The ash roughly retains the shape of fibres but can be easily crushed to powder.

Animal-based fibres such as silk and wool also burn to give ash but in much lesser quantity. Sometimes they burn producing a small bead which gets crushed easily. Moreover they burn with an odour, similar to that of burning meat.

Synthetic fibres usually burn much faster than plant or animal fibres. When exposed to flame, they melt and then decompose, producing a lot of heat. These do not form any ash but form a bead which is not easy to crush.

Safety Precautions: Be very careful while doing the burning tests. Do not be too close to the flame or the burning fibre and do not throw burnt threads around. Some fibres burn very vigorously and their melts can also cause burns or damage to surrounding objects. Keep water in a watch glass or a container nearby, and put the burnt fibres in the water.

Fibres under the microscope

Different fibres have different shapes and surface features that can be seen under a microscope. Depending on the conditions in which the fibre has formed (shape of original plant cell or animal cell(s) and how the fibre was dried), it can have a circular, elongated, or irregular cross section. Cotton fibres, in particular, have a non-circular cross-section due to which the twists in the fibres can be easily observed under a microscope. Plant fibres generally have rough surfaces. In a bundle of natural fibres, fibre thickness may also vary from one fibre to another.

Synthetic fibres usually have circular cross-sections and smooth surfaces because they are formed by passing molten polymer through circular holes, similar to the way noodles are made. Thickness of a synthetic fibre is uniform along the length of a fibre, and is also the same for different fibres in a thread.

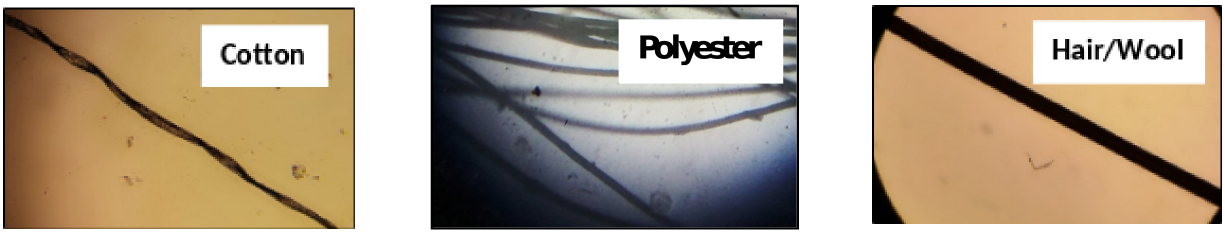

Figure 2: Fibres under microscope

Animal fibres such as wool and silk have circular cross-sections and surfaces smoother than plant fibres but rougher than synthetic fibres. Wool/hair also have scales of the surface (which may not be observed if the wool/hair has been treated with strong bleaches, dyes, or chemicals that damage the hair scales).
However, all fibres on use (even synthetic fibres) usually develop surface roughness due to wear and tear.

Q1. What differences do you observe between the microscopic images of cotton and polyester fibres in figure 2? Are there any other different features of these fibres that you can conclude from these observations?

> This question is to familiarize students with seeing differences in fibre shapes, so that they can easily notice these features while observing the fibres under a microscope.

Task 1: Known fibres

Take a cotton and a polyester or synthetic thread (like nylon or acrylic).

1. Observe the fibres in each thread with the naked eye. Note their physical properties such as shiny, dull appearance, and if they are smooth or rough to touch.

Fibre	Observations (Shiny/dull, rough/smooth texture)

Table 1

2. Take a tray, and fix a candle in the middle of it. Fill the tray slightly with water. Light the candle. Hold the thread with a pair of forceps or tongs and bring one end of it close to the flame. Note your observations about the thread burning in the following table. Collect the ash/bead formed on

a watch glass. [Caution: Keep your head/body parts away from flame as some fibres burn very vigorously. Extinguish flames of any burning fibres in water; do not throw them anywhere else.]

Note the following observations for each fibre.

Sr. No.	Did it melt? (Yes/No)	Any smoke? (Yes/No)	Smell (like burning paper or plastic)	Ash/ Bead formed	Afterglow? (Yes/No)

Table 2

> Due to excitement, students may start burning too many fibres at once, which increases the risk of accidents. Only one thread should be burnt at a time. Any burnt fibre should be put in water.

3. Take some water in a glass. Check if it is acidic or basic with a litmus paper. Add one drop of water to the ash/bead on the watch glass. Wait for 1-2 minutes and check with litmus papers (red and blue)/a drop of phenolphthalein solution/a pinch of turmeric. Has the water become acidic or basic on contact with the ash/bead? Note: Ash or bead will not completely dissolve in water; some solid will remain in both cases.

Sr. No.	Thread burnt	Ash + Water (Neutral/Basic/Acidic)

Table 3

> It is important to test with both blue and red litmus. If only one type is available, then you can convert one into the other. To convert blue litmus paper to red, dip blue litmus paper in a dilute acid solution, wash it with water and use. Similarly, to convert red litmus paper to blue, dip red litmus paper in a dilute alkaline solution, wash with water and use. Acid/base/neutral nature can be confirmed by using both blue and red litmus papers.

4. Now observe the thread under a microscope as described below. (Did you know that Antonie van Leeuwenhoek , considered to be a pioneer of microbiology, started his journey as a colth merchant. He started using self-made lens arrangements to observe the quality of fibres in his shop. This setup of lenses was a rudimentary microscope which later also helped him to study animals and organisms in detail).

A thread usually has several fibres bundled together. Using a pin or forceps, loosen out the fibres in a thread and pull out a fibre. Put the fibre on a glass slide and cover it with a cover slip. Observe it under 10X objective. If you are not able to focus on the fibre, make sure that the fibre is under the objective lens and while focusing, keep the distance between the lens tip and the cover-slip is around 0.5 cm.

Note the features of the fibre. Next put 3-4 fibres together on the slide and observe the variation in the thickness of different fibres.

It is important to emphasize that threads are not fibres. Particularly for microscopy, if students put whole threads on the slides, then they will not be able to see individual fibres clearly (in some cases the bundle of fibres may block light completely from entering the lens). Students may need guidance to pull out the fibres from a thread.

Since some of the students may be using the microscope for the first time, they may need some guidance about what to observe even on a focused slide. Sometimes, students just see the dust particles and imagine that to be the cross section of the fibre. If they have not been able to focus on the fibres and are looking at unfocussed slides, such confusions may increase.

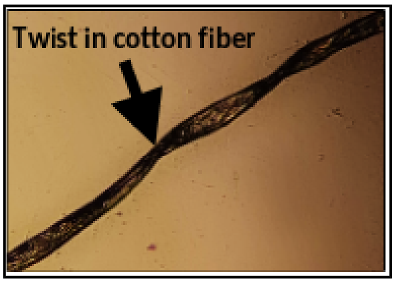

Figure 3

Q2. Is the fibre that you observe uniform in thickness along the length or is the thickness different at middle and ends of the fibre (To see this, you will to move the slide on the stage to see it from one end to another end)?

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Q3. Do you observe twists in the cotton fibres? ______________

Q4. Do you observe folds in the cotton fibre? ______________

Q5. What can you say about the thickness of various fibres? ______________

Now sketch the shape of the fibre observed under microscope, and write its features:

Cotton
Magnification_____X

Polyester
Magnification_____X

Fibre	Fibre description (straight or twisted, transparent or opaque, uniform or variable thickness along length)	Are all the fibres same or different in shape?

Cotton		
Polyester		

> Cotton fibres should have varying thickness across the length and also across different fibres, whereas synthetic fibres should have the same thickness across length and across different fibres. While sketching, students should focus on the shape and features of a single fibre instead of drawing too many fibres.

See the sketches done by your classmates and copy here at least one different sketch of cotton and polyester as drawn by one of your classmates .

Cotton:	Polyster:

Q6. Based on your observations, what can you conclude about the features/properties of cotton (a plant-based fibre), and polyester (a synthetic fibre).?

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> Here, the students should write about presence/absence of twists, thickness, colours of fibres. They should also note if the fibres look opaque/transparent, smooth/rough, or any other features they observe.

Q7. Why do you think the ash obtained from burning cotton changes the (acidic/basic) nature of water, and the bead from polyester did not?

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> Here students should relate the presence of metals in cotton, which can convert to oxides or other salts during combustion, which can make water alkaline. This feature arises because metal compounds do not escape as gases during combustion. Polyester fibre has no metals in it. When kept in flame, the polymer melts and forms another cross-linked polymer which does not react with water. Hence, the molten bead doesn't change the property of water it is kept in contact with.

Task 2: Wool/hair (animal fibre)

Take a woollen thread or human hair (because real wool is also the hair of some animal) and perform the following steps.

1. By burning test as done in Task 1, check if it is natural or synthetic.
   (If it is synthetic, then try finding a real wool/hair sample.)

How did it melt (smell, smoke, afterglow, ash/bead formed)?			
Ash/bead + water: Acidic or basic or neutral?		Crushable?	

2. Separate fibres out of the thread, as done in Task 1 and observe the fibres under microscope.

Fibre: ____________
Magnification_____X

Fibre: ____________
Magnification_____X

Fibre description (straight or twisted, transparent or opaque, uniform or variable thickness along lenght)
Are all fibres same or different in shape?

> Note that students may see features different from the ones shown in figures 2 and 3 above. Make sure they draw features that they see under the microscope and not what is shown in this unit.

The science behind the burning tests

Now that you have done some burning tests, let us try to understand why plant-based, animal-based, and synthetic fibres burn differently.

- Plant-based fibres (cotton, linen, hemp, sugarcane, jute) have high amount of cellulose which burns easily. However, these also have some amount of silica and metals (~0.1-0.6% by mass) which lead to ash formation (~0.5-1.2% by mass). These fibres burn slowly with a flame. When the flame goes off, the remaining silica and metal compounds glow red like burning coal. As the burnt fibre/ash cools down, the afterglow disappears and fine ash is obtained.

- Synthetic fibres usually do not have silica or metals. These are often produced from polymers made of non-metallic elements such as carbon, nitrogen, oxygen, and hydrogen. These fibres have low melting temperatures. Therefore when exposed to flame, these melt and then decompose. Burning a synthetic fibre produces a lot of heat but may or may not form smoke (Smoke formation depends on percentage of carbon in the polymer. If carbon percentage is high, then all of carbon is not able to get enough oxygen to form carbon dioxide, and hence particles of unburnt carbon and related substances are formed which become smoke).
- Animal-based fibres (wool, silk) are predominantly made of proteins (such as keratins) which burn with a smell, similar to obtain from burning of other proteins such as meat.

Task 3: Unknown fibre

1. Take a thread of unknown material. By observing this thread with the naked eye, guess if it is a natural or a synthetic fibre.

Sr. No.	Observations	Natural/Synthetic

Table 5

2. Conduct the burning test for the thread as done in Task 1, identify if it is natural or synthetic. [Remember the precautions of keeping your head/body parts away from flame as some fibres burn very vigorously. Extinguish flames of any burning fibres in water; do not throw them anywhere else.]

> Students may not be able to identify the fibre correctly and may give multiple possible identities of fibres, which is acceptable at this stage. Many natural fibres such as silk and even processed cotton may look like synthetic fibres under the microscope. Hence, correct identification of fibres is possible only with a combination of multiple tests.
> If different fibres are blended in a thread, the burning test may provide confusing results. Under the microscope, looking at multiple fibres from the same thread may reveal this mix of fibres.
> If the fibre is from an old and used cloth, it may look very different (more rough and damaged) under the microscope than a new fibre. Hence, try to use a new thread/cloth if possible.

3. Separate the fibres out of the thread, as done in Task 1, and observe the fibres under a microscope.

Sketch	Describe a single fibre	Variation in a bunch of fibres

Table 6

Note: Do check if the thread you have is not mixed (i.e., if it consists of more than one kind of fibres) and hence may give properties of both kinds of fibre, such as giving both ash and bead on burning.

Based on the above tests, try to identify the fibre: The observed fibre is ____________________because____

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4. Paste/staple a sample of the thread here.

Task 4: Fibres and Society

As a customer, the nature of fibres is important to us. But have you thought about how the livelihoods of millions of people depend on the fibres that we choose to use?

Q1. For each of the fibres that you identified, list the people who are involved from the production stage of this fibre to the sale of final product (fabric, threads or garments) when you buy them?

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Q2. Do you know of any fibres that are produced in your locality and are used for making textiles, ropes, or any other materials? If yes, briefly describe the process used to prepare the threads from the fibres.

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Q3. Based on what you have learned above, can you say if the wicks for candles and oil lamps can be made using synthetic fibres? Why?

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Q4. Use in wick-making continues to be an important reason for the sale of cotton. Name the professions that depend on the use of cotton in wicks.

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Social importance of fibres

Why should so many students in the country study the properties of fibres? A simple answers is: because fibres are a source of livelihood to millions of people—farmers, sheep rearers, workers of fibre processing mills, the traders of fibres, weavers, dyers, fashion designers, industrialists who produce raw materials for these industries, tailors, retail and wholesale dealers of fabrics and garments, research scientists and engineers working on fibres.

Secondly, fibres can be a tool to learn a lot of science as we have seen above.

Moreover, even though we have so many varieties of synthetic fibres, natural fibres still have a lot of value in our lives. For example, we cannot use synthetic fibre to make wicks for candles and oil lamps because they do not support a falme. When synthetic fibres are burnt, they melt without forming ash. The bead formed prevents evaporation of wax or oil vapours and does not support a flame.

This activity may be extrapolated to explore answers to the following questions-

1. What kind of materials when burnt would generate ash? Here, you can extend the general principle: the materials that contain metal compounds and silica would generate ash. Most natural materials such as wood, leaves, feathers, etc, have this property. In some cases such as processed cotton where all metals and silica are chemically removed, no ash may be obtained.
2. Which fibres are easier to tie a knot with, and which are easy for weaving? Fibres that have smooth surface are easy to weave with as threads pass over and under each other easily. But some amount of friction is desirable even there to hold the fibres and thread in place. In contrast, if the fibre surface is too rough, then weaving using their threads requires lot of force to slide one thread past other threads. Threads may also break frequently during such weaving. For knots, surface roughness helps in keeping knots in places. In thread made of smooth fibres, knots loosen due to surface smoothness. Thus, a knot in jute rope is much more stronger than a knot in nylon rope.

Understanding the burning process

Burning of fibres or any other material is a complex process and usually involves many steps:

1) *Decomposition of the constituent substances*: During burning, heat leads to breakdown of the substance molecules into smaller molecules. These smaller molecules may remain as solid or liquid (depending on temperature of flame), may get oxidized if oxygen is available, and/or may escape as gaseous products.
2) *Melting of the constituent substances*: If the melting point of any substance in the burning material is reached within the combustion conditions, it melts and may start flowing. In some cases, such as cellulose (in cotton), melting is not observed during burning because cellulose starts to decompose at a temperature below its melting temperature.
3) *Oxidation*: If oxygen is available, the substances available combine with oxygen to form oxidized products. If the supply of oxygen is sufficient, the non-metallic substances may be released as gases such as H_2O, CO_2, SO_2, NO_2, etc., and the metallic and metalloid elements form oxides such as Na_2O, CaO, SiO_2, etc. These oxides may combine with CO_2 or SO_2 to form carbonates, sulphites, etc.

Suggested readings

1. For a very good review on different kinds of plant, animal and synthetic fibres, this book is a useful read and is available in Indian Edition (burning test has been described on page 35). Sara J. Kadolph (2009). Textiles, 10^{th} Edn, Dorling Kindersley India Pvt. Ltd., Delhi.
2. For a detailed understanding of the structure and properties of cotton fibre, this book may be read, also available as a soft copy on internet. Philip J Wakelyn et al. (2007) Cotton fibre Chemistry and Technology, CRC Press, Boca Raton, Florida.

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