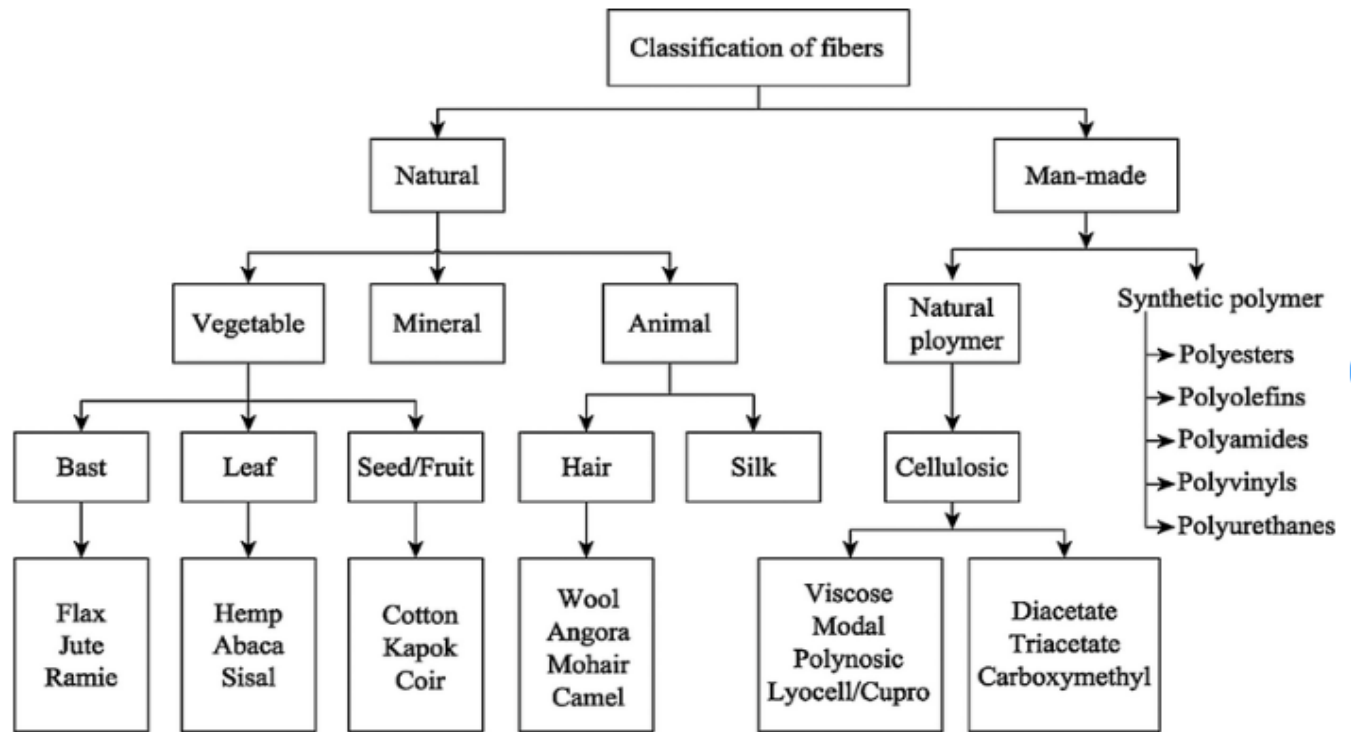


Chapter One: Classification of Fibers



Classification of fibers.

1-1-Vegetable fibers or cellulosic fibers

The fibers that are derived from plants are called vegetable fibres. The basic material of all plant life is cellulose. Cellulose is made up of elements like carbon, hydrogen and oxygen. These cellulose fibres have certain common properties like low resilience, high density, and good conductor of heat. They are highly absorbent and are resistant to high temperature. Cotton flax, jute, ramie are some of the examples of vegetable fibres.

1-2-Animal fibres

The fibres which are obtained from animals are called animal fibres. Wool and silk are common examples of animal fibres. They are made up of protein molecules. The basic elements in the protein molecules are carbon, hydrogen, oxygen and nitrogen. Animal fibres have high resiliency but weak when wet because they are bad conductors of heat.

1-3-Mineral fibres

They are the inorganic materials shaped in to fibres and are mainly used in the fire proof fabrics. Asbestos is the example of mineral fibre. Mineral fibres are fire proof, resistant to acids and are used for industrial purposes.

1-4-Man made fibres

These refer to those fibres that are not naturally present in nature and are made artificially by man. Man made fibres have high strength, strong when wet low moisture absorption characteristics. Examples of manmade fibers are viscose rayon, acetate rayon, nylon, polyester etc. Depending on raw material chosen for making of the fibres they are classified as cellulosic fibres, protein fibres and synthetic fibres.

1-5-General properties of textile fibres

1. **Staple Fibres:** Is the more common length of fibres.
2. **Filament:** Long continuous fibres strands of indefinite length measured in yards or meters fibres of continuous length long enough to be used in fabric.
3. **Texture:** It is the tactile sensation experienced when hand is passed over a surface. Staple fibres and fabrics made from staple are lightly rough while filaments and fabrics made from filaments fibres are smooth.
4. **Resilience:** It means that when fibre is compressed and later when the pressure

is released, it will tend to return to its original shape. Resistance to compression varies from fibre to fibre. This quality causes the fabric to be wrinkle resistant with the resistance varying according to the degree of elasticity inherent in the fibre. Wool has good resiliency while it is poor in cotton.

5. **Luster:** It is seen when light reflected from a surface. It is more subdued than shine. Silk and synthetics have more luster than cellulosic fibres. Synthetic fibres have high luster which is purposefully removed during spinning.
6. **Static Electricity:** It is generated by the friction of a fabric when it is rubbed against itself or other objects. If the electrical charge that is not conducted away, It tends to build up on the surface and when fabric comes in contact with a good conductor a shock or transfer occurs. This transfer may sometimes produce sparks. This is more feel during hot and humid conditions.
7. **Crimp:** Wool fibre is more or less wavy and has twists. This waviness is termed as crimp. Finer the wool more will be the crimps in it. Marino wool will have 30 crimps per inch while coarse wool has only one or two. This property of having crimps gives elasticity to the fibre.
8. **Elasticity:** It is the ability of stretched material to return immediately to its original size.

Questions

Fill in the blanks

1. The fibres that are derived from plants are called _____ fibres.
2. The basic material of all plant life is _____.
3. _____ and _____ are common examples of animal fibres.
4. Mineral fibres like _____ are used in fire-proof fabrics.
5. Man-made fibres are _____ present in nature and made _____ by man.
6. Wool has good _____ while it is poor in cotton.
7. The waviness in wool fibres is called _____.
8. Silk and synthetics have more _____ than cellulosic fibres.
9. Static electricity is generated by _____ of a fabric when rubbed.
10. The ability of stretched material to return to its original size is called _____.

B. Multiple-choice questions

1. Which of the following is **not** a vegetable fibre?
 - a) Cotton
 - b) Jute
 - c) Silk
 - d) Flax**Answer:** c) Silk
2. Animal fibres are made up of:
 - a) Cellulose molecules
 - b) Protein molecules
 - c) Mineral particles
 - d) Plastic polymers**Answer:** b) Protein molecules
3. Which element is **not** found in protein molecules?
 - a) Nitrogen
 - b) Oxygen
 - c) Carbon
 - d) Sodium**Answer:** d) Sodium

4. The fibre that is fireproof and resistant to acids is:

- a) Wool
- b) Asbestos
- c) Jute
- d) Nylon

Answer: b) Asbestos

5. Man-made fibres are usually:

- a) Weak when wet
- b) High in moisture absorption
- c) Strong when wet
- d) Naturally found in plants

Answer: c) Strong when wet

6. Which fibre has about 30 crimps per inch?

- a) Coarse wool
- b) Cotton
- c) Marino wool
- d) Flax

Answer: c) Marino wool

7. Which fibre type is a **good conductor of heat**?

- a) Cellulosic fibre
- b) Animal fibre
- c) Mineral fibre
- d) Synthetic fibre

Answer: a) Cellulosic fibre

8. Static electricity is felt more during:

- a) Cold and dry conditions
- b) Hot and humid conditions
- c) Rainy and windy conditions
- d) Cloudy weather

Answer: b) Hot and humid conditions

C. Enumeration (List or Define)

1. List **four types of textile fibres** based on their source.
2. Write **three examples of vegetable fibres**.
3. Mention **two properties of animal fibres**.
4. List **any three general properties of textile fibres**.
5. Give **two examples of man-made fibres**.

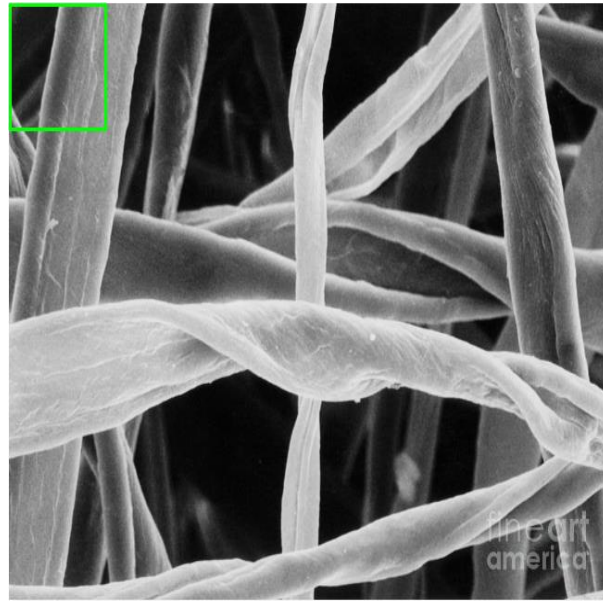
Chapter Two: Seed Fibers - Cotton Fibers

2-1-Introduction:

Cotton is a natural fiber (vegetable fiber) obtained from the seed of the cotton plant. Chemically, it is represented by the chemical formula. For most apparel and home end uses, cotton fiber is particularly well suited because of its combination of strength, durability, and comfort properties. Cotton also has good temperature resistance, which is important in textile-mill dyeing and finishing processes and consumer care.



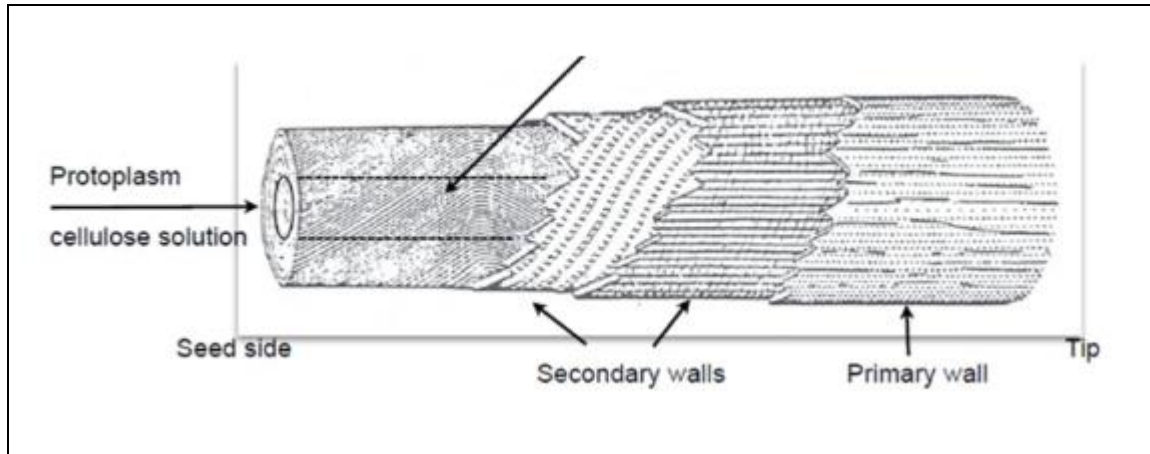
Cotton flower



Cotton fiber

2-2- Maturity

The maturity of cotton is defined in terms of the development of cell wall. A fully mature fiber has a well-developed thick cell wall. On the other hand, an immature fibre has a very thin cell. The fibre is to be considered as mature fibre when the cell wall of the moisture-swollen fibre represents 50-80% of the round cross section, as immature when it represents 30-45% and as dead when it represents less than 25%.



Cross section of cotton fibers

2-3-Immature fiber leads to:

- Nipping
- Loss of yarn strength
- Varying dye ability
- High proportion of short fibres
- Processing difficulties mainly at the card

Mature fibre → Dye absorb↑

Immature fibre → Dye absorb↓.

2-4-Properties of Cotton Fibres:

Properties of cotton fibre can be divided into two parts, one is according to physical structure and another is using process.

A. According to physical structure:

1. **Length of cotton fiber:** Physically the individual cotton fibre consists of a single long tubular cell. Its length is about 1200-1500 times than its breadth. Length of cotton fibre varies from 16mm to 52 mm depending upon the type of cotton.
 - Indian cotton- 16-25 mm
 - American cotton- 20-30 mm
 - Sea Island- 38-52 mm
 - Egyptian cotton- 30-38 mm
2. **Fineness of cotton fiber:** Longer the fibre, finer the fibre in case of cotton fibre. It is expressed in term of decitex and it varies from 1.1 to 2.3 decitex.
 - Indian = 2.2-2.3 dtex
 - American = 2.1-2.2 dtex
 - Egyptian = 1.2-1.8 dtex
 - Sea Island = 1.0-1.1 dtex
3. **Strength and extension of cotton fiber:** Cotton fibre is fairly among natural fibres in relation to tenacity which is 3-3.5g/dtex. Its tensile strength is between wool and silk fibre but disadvantage is low extension at break which is 5-7%.
4. **Elastic properties of cotton:** Recovery from deformation of cotton fibre, yarn or fabric from applied load is very low. By applying heat it can't be achieved. This property can be achieved by:
 - Chemical treatment to improve crease recovery, but the problem is the materials become harsher due to chemical treatment.
 - Blending or mixing of cotton with elastic fibre, e.g. polyester, blend ratio depends on the end use of the fabric. The initial modulus is fairly high = 0.5 g/dtex (wool = 0.25 g/dtex).
5. **Cross-section:** Cross-section of cotton fibre is some what ribbon like. The cell wall is rather thin and the lumen occupies about two-third of the entire breadth

and shows up very prominent in polarized light. Fibre cross-section becomes round when mercerized.

6. **Appearance:** Cotton fibre is fairly short, fine and creamy white color. Color of the fibre depends on 'soil of growth. By adding chemicals in the soil, color of the cotton fibre may be varied.
7. **Crimp:** Cotton fibre is more or less twisted on its longitudinal axis which can not be seen from out side is called convolution. The twist in the fibre does not to be continuous in one direction i.e. if at first right direction, then left direction. This property of cotton fibre helps in spinning.

B. According to using process:

- **Comfortable:** Cotton fiber has large amorphous portion and this is why the air can be in and out through cotton fiber. So, the fabric made by cotton fiber is quite comfortable to use.
- **Soft Hand:** Cotton fiber is too much regular fiber and if properly ginned; this fibre can be the best soft hand feeling fibre amongst the others.
- **Absorbent:** Cotton fiber has high absorbency power and this is why this fiber can be died properly and without any harassment.
- **Good Color Retention:** If the printing is applied on cotton fiber, it seems it doesn't spread the color outside the design. So printing efficiency is good on cotton fibre.
- **Machine Washable & Dry Cleanable:** It is seen that some fibers can't be dried or washed due to its sensitivity and weak fastness properties but in case of Cotton fiber you will have large number of options to choose. You can easily wash the cotton made fabric by machines and even you will be able to dry this fiber by using electronic drier.
- **Good Strength:** If you want to seek an average strength which might be enough

for you; then cotton fiber can be your ultimate choice. The strength of cotton fiber is quite good.

- **Cotton Fibre Drapes Well:** The drape-ability of cotton fibre is awesome. You can use the cotton fibre made fabric in any kind of wear which needs more flexibility and drapes.
- **Sewing & Handling Is Easy:** The sewing efficiency on Cotton made fabric is easier and comfortable than other fiber. This is why the demand of cotton made fabric is higher in all over the world.

Uses of Cotton:

Cotton fiber is a versatile fibre which has wide variety of uses. But the Cotton fibre is mostly used on the Apparel Industry to make the wearing cloth like Sweaters, Skirts, Shirts, Swimwear, Kids wear, Blouses, Pants, Hosiery and to make other type of dresses.

2-5- Chemical properties

- **Action of acids and alkalies:** Strong acids will destroy the fibres immediately. Dilute inorganic acids will weaken the fibre and if left dry will rot it. Therefore after treatment with acidic solutions cotton articles should be thoroughly rinsed in water. They are affected very little by organic acids. They are also quite resistant to alkalis even to strong, caustic alkalies at high temperature and pressure. In 8% NaOH cotton fibres swells, spirals, twisted uncoil and shrinks and become thicker. The resultant fibre is smoother, lustrous, and stronger and has increased water and dye absorption.
- **Effect of bleaching:** These have no effects until used in uncontrolled conditions and with heat.
- **Effect of sunlight and weather:** Ultraviolet rays of sunlight affect the strength of fibre and change the colour to yellow when exposed to prolonged period.

Pollution also effect fibre. Concentrated and diluted mineral acids like sulphuric acids will discolour fibre.

- **Affinity to dyes:** Cotton takes in dyes better than linen but not as readily as silk and wool. If a mordant is used cotton is easy enough to dye mordant colours, direct or substantive dyes should be applied to the cotton.
- **Effect of perspiration:** Both acidic and alkaline perspiration discolours the fibre.

2-6- Biological properties

- **Resistance to microorganisms:** The mildew and bacteria damages cotton.
- **Resistance to insects:** Moths and beetles will not affect or damage the cotton. But the sliver fish eats the cotton cellulose.

Questions

True or False (A)

1. Cotton is an animal fiber obtained from the hair of sheep.
2. Cotton is a vegetable fiber obtained from the seed of the cotton plant.
3. A mature cotton fiber has a very thin cell wall.
4. Immature fibers cause loss of yarn strength and uneven dyeing.
5. Sea Island cotton has the shortest and coarsest fibers.
6. Cotton fibers become more lustrous and stronger after mercerization.
7. Cotton fiber has high elasticity and easily recovers its shape after stretching.
8. Cotton fibers are destroyed by strong acids but resist strong alkalis.
9. Exposure to sunlight for a long time may turn cotton fibers yellow.
10. Moths and beetles seriously damage cotton fibers.

B. Explanation Questions (Short Answer)

1. Explain what is meant by *maturity* in cotton fibers.

2. Describe how immature cotton fibers affect the quality of yarn and dyeing.
3. Why is cotton considered a comfortable fabric for clothing?
4. What happens to cotton fibers during the process of **mercerization**?
5. Explain why cotton fabrics are easy to sew and handle.
- 6.
7. Why is it necessary to rinse cotton articles well after acid treatment?
8. What is the effect of sunlight and weather on cotton fibers?
9. How does the soil of growth affect the appearance of cotton fibers?
10. Describe the shape of the cotton fiber's cross-section and its effect on the appearance.
11. Explain why cotton fibers have poor elasticity.

C. Mention the Benefit of:

1. Mention the benefit of **cotton's high absorbency**.
2. Mention the benefit of **cotton's good color retention**.
3. Mention the benefit of **mercerization of cotton fibers**.
4. Mention the benefit of **blending cotton with polyester**.
5. Mention the benefit of **cotton's good strength and drape**.
6. Mention the benefit of **cotton being machine washable and dry cleanable**.
7. Mention the benefit of **using mature cotton fibers** in textile production.

Chapter Three: Bast fibers

Natural Bast Fibers are strong, cellulosic fibers obtained from the phloem or outer bark of jute, kenaf, linen and hemp plants. They are annually renewable crops, growing in 90 to 100 days. The fiber is around the outside of the plant and comprises one-third of the weight. The center (core) resembles balsa wood and has many uses, including animal bedding and oil absorbents. In India and Bangladesh, it is mostly used as firewood.

Unlike synthetic fibers, bast fibers are made up of bundles of fibers. These bundles are broken down mechanically or chemically to achieve the fineness required. The degree of this breakdown, in turn, dictates their end use.

3-1-Jute Fibres

Jute is a bast fiber used for sacking, burlap, and twine as a backing material for tufted carpets. It is a long, soft, shiny fiber that can be spun into coarse, strong threads. It is one of the cheapest natural fibers, and is second only to cotton in amount produced and variety of uses. Jute fibers are composed primarily of the plant materials cellulose, lignin, and pectin. Both the fiber and the plant from which it comes are commonly called jute. It belongs to the genus *Corchorus* in the basswood family, Tiliaceae.

3-1-1 Properties of Jute Fiber:

1. Jute fibre is 100% bio-degradable and recyclable and thus environmentally friendly.
2. Jute is a natural fibre with golden and silky shine and hence called The Golden Fibre.
3. Jute is the cheapest vegetable fibre procured from the bast or skin of the plant's

stem.

4. It is the second most important vegetable fibre after cotton, in terms of usage, global consumption, production, and availability.
5. It has high tensile strength, low extensibility, and ensures better breathability of fabrics. Therefore, jute is very suitable in agricultural commodity bulk packaging.
6. It helps to make best quality industrial yarn, fabric, net, and sacks. It is one of the most versatile natural fibres that has been used in raw materials for packaging, textiles, non-textile, construction, and agricultural sectors. Bulking of yarn results in a reduced breaking tenacity and an increased breaking extensibility when blended as a ternary blend.
7. Unlike the fiber known as hemp, jute is not a form of (Cannabis). Therefore it can be much more easily distinguished from forms of Cannabis that produce a narcotic.
8. Jute is one of the most versatile natural fibres that has been used in raw materials for packaging, textiles, non-textile, and agricultural sectors.
9. Jute stem has very high volume of cellulose that can be procured within 4-6 months, and hence it also can save the forest and meet cellulose and wood requirement of the world.
10. The best varieties of Jute are (Golden shine) and White (Whitish Shine).

3-1-2- Uses of Jute Fiber

Jute is the second most important vegetable fibre after cotton; not only for cultivation, but also for various uses. Jute is used chiefly to make cloth for wrapping bales of raw cotton, and to make sacks and coarse cloth. The fibres are also woven into curtains, chair coverings, carpets, area rugs, hessian cloth, and backing for linoleum. While jute is being replaced by synthetic materials in many of these uses,

some uses take advantage of jute's biodegradable nature, where synthetics would be unsuitable. Jute butts, the coarse ends of the plants, are used to make inexpensive cloth.

Traditionally jute was used in traditional textile machineries as textile fibres having cellulose (vegetable fibre content) and lignin (wood fibre content). But, the major breakthrough came when the automobile, pulp and paper, and the furniture and bedding industries started to use jute and its allied fibres with their non-woven and composite technology to manufacture nonwovens, technical textiles, and composites.

3-1-3-Processes of Jute Extraction

- **Retting:** Retting is a process in which the tied bundles of jute stalks are taken to the tank by which fibres get loosened and separated from the woody stalk. The bundles are steeped in water at least 60 cm to 100 cm depth. The retting process is completed in 8 to 30 days, when the barks separate out easily from the stick or wood and the fibres are ready for extraction. A development in recent years is adoption of ribbon retting technology in jute growing trade of the country. There are other methods for retting as river retting, dew retting.
- **Stripping (Fiber Extraction):** Stripping is the process of removing the fibres from the stalk after the completion of retting. Fibres are removed from the stalk by any one of the following methods:
 - (i) Single plants are taken and their fibers are taken off.
 - (ii) Taken off a handful of stalks, breaking it in a to and fro motion in water.
 - (iii) Washing the stalks first by standing in waist deep water and then stripping afterwards.
- **Washing and Drying:** Extracted fibres are washed in clean water. The dark

colour of fibres can be removed by dipping them in tamarind water for 15 to 20 minutes and again washed in clean water. After squeezing excess water the fibres are hang on bamboo railing for sun drying for 2-3 days.

- **Bailing and Packing:** The jute fibre is graded into tops, middles, B, C and X-bottoms. Packing into Kutchha bales about 250 pounds for use in the home trade. they are transported to jute market or direct to jute mills.



Process of jute extraction

What is Linen Fiber?

Linen fiber is a **natural cellulose fiber** obtained from the **stem of the flax plant** (*Linum usitatissimum*). It is one of the **oldest textile fibers** known to humans and is famous for its **strength, luster, and cool feel**.

Physical Properties of Linen Fiber

Property	Description
Source	Stem of the flax plant
Color	Light yellow to grayish
Length	25 to 150 cm (long staple fiber)
Strength	Very strong — stronger when wet
Elasticity	Low (creases easily)
Luster	Natural sheen and smooth surface
Moisture Absorption	High — feels cool and comfortable
Density	1.5 g/cm ³ (heavier than cotton)
Thermal Conductivity	Good — keeps the body cool
Durability	Very durable and long-lasting

Chemical Composition

Component Percentage (%)

Cellulose	70–75
Hemicellulose	15–20
Lignin	2–5
Wax & Pectin	2–3

Uses of Linen Fiber

- Clothing (shirts, trousers, suits)
- Home textiles (bed sheets, curtains, tablecloths)
- Canvas and upholstery
- Industrial fabrics and ropes
- Medical dressings and bandages

Process of Linen Fiber Extraction

Similar to jute, linen is extracted through **retting** of flax stems, followed by:

1. **Harvesting**
2. **Retting** (soaking stems to loosen fibers)
3. **Breaking** (removing woody parts)
4. **Scutching** (separating fibers)
5. **Hackling** (combing to make fine strands)
6. **Spinning**

Effect of Acids, Alkalis, and Insects on Linen Fibers

1. Acids:

Linen is sensitive to strong acids. Concentrated acids, such as sulfuric acid, can hydrolyze the cellulose in linen fibers, causing them to weaken, break down, or disintegrate. Even mild acidic conditions over time can damage the fiber and reduce its lifespan.

2. Alkalis (Bases):

Linen is more resistant to alkalis than to acids. Mild alkalis like sodium carbonate (washing soda) or soap do not significantly harm linen and are often used in cleaning. However, strong alkalis such as sodium hydroxide (caustic soda) can degrade cellulose if exposure is prolonged or at high temperatures.

3. Insects:

Unlike wool, which is a protein-based fiber and vulnerable to insect damage (e.g., moths), linen is made of cellulose and is generally not affected by most insects. However, silverfish and termites can feed on cellulose materials, including linen, especially in humid and dark environments.

Main Uses of Linen Fibers

Clothing:

Linen is widely used to make shirts, dresses, trousers, jackets, and summer wear due to its breathability and cool feel.

Home Textiles:

Linen is commonly used for bed sheets, pillowcases, tablecloths, napkins, and curtains.

Upholstery and Furnishings:

Linen is used in furniture coverings, cushion covers, and wall coverings because of its durability and elegant texture.

Towels and Bath Products:

Linen is used in making towels, bathrobes, and spa products thanks to its high absorbency and quick-drying nature.

Industrial Uses:

Linen is used in bookbinding, canvas for painting, and sometimes in composite materials.

Decorative Items:

Linen is also used in embroidery, crafts, and luxury decorative items due to its natural look and texture.

Eco-Friendly Fashion and Products:

Because it is biodegradable and made from the flax plant, linen is popular in sustainable and eco-conscious product lines.

Questions

True / False Questions

1. Linen fiber is obtained from the seed of the flax plant. → ✗
 2. Linen becomes stronger when wet. → ✓
 3. Linen has high elasticity. → ✗
 4. Linen is heavier and stronger than cotton. → ✓
-

Multiple Choice Questions (MCQs)

1. Linen fiber is obtained from the _____ of the flax plant.
 - a) Flower
 - b) Stem
 - c) Leaf
 - d) Seed

➔ **Answer:** b) Stem
2. The main chemical component of linen is:
 - a) Protein
 - b) Cellulose
 - c) Lignin
 - d) Keratin

➔ **Answer:** b) Cellulose
3. Which of the following is a major property of linen?
 - a) High elasticity
 - b) Shiny and cool feel
 - c) Low moisture absorption
 - d) Weak when wet

➔ **Answer:** b) Shiny and cool feel

Chapter Four Leaf Fibers

4-1-Sisal Fiber:

Sisal Fiber is one of the most widely used natural fiber and is very easily cultivated. It is obtained from sisal plant. **Sisal fibers are natural plant fibers** obtained from the **leaves of the Agave sisalana plant**, which grows mainly in **tropical and subtropical regions** (such as Africa, Brazil, Mexico, and parts of Asia).

Origin

- The **Agave sisalana** plant has long, sword-shaped leaves.
- Each leaf contains many long, tough fibers that can be extracted, washed, and dried.
- These fibers are known as **sisal fibers**.

4-2-Main Characteristics

- **Color:** Creamy white to yellowish.
- **Texture:** Hard, coarse, and stiff.
- **Length:** 60–120 cm (long fibers).
- **Strong and durable**, but **not very elastic**.
- **Biodegradable** and **environmentally friendly**.

4-3-Uses

Because of its **strength and stiffness**, sisal is widely used for:

- Ropes and cords
- Mats and carpets
- Brushes
- Sacks and handicrafts
- Reinforcement in **composite materials** (bio composites)

4-4- Environmental Importance

- Sisal is **renewable** and **biodegradable**.
- It is an **eco-friendly alternative** to synthetic fibers like nylon or polyester.

Sisal fiber is a strong, natural plant fiber extracted from the leaves of the Agave sisalana plant, commonly used for ropes, mats, and eco-friendly industrial materials.

4-5-Physical Properties of Sisal Fibers

1. Source and Appearance

- Sisal is a **natural plant fiber** obtained from the leaves of the Agave sisalana plant.
- The fibers are **coarse, straight, and creamy white to yellowish** in color.
- They have a **hard and stiff texture** compared to other natural fibers like jute or hemp.

2. Length and Diameter

- Fiber length: **0.6 to 1.2 meters** (long fibers).
- Diameter: **100–300 micrometers** (varies depending on plant and processing).

3. Density

- **Specific gravity:** About **1.45 g/cm³**.
- Sisal is **heavier than wool** and **lighter than flax**.

4. Moisture Absorption

- **Moisture regain:** Around **10–12%** at standard conditions.
- Sisal absorbs less moisture than wool but more than synthetic fibers.

5. Tensile Strength

- Very **high tensile strength**, around **400–700 MPa**.

- This makes sisal suitable for **ropes, mats, brushes, and composites**.

6. Elasticity

- **Low elasticity** (does not stretch much).
- This means it is **strong but not flexible**.

7. Thermal Properties

- Starts to decompose at about **220–250 °C**.
- Burns easily and produces ash (not flame-resistant).

8. Durability

- **Good resistance to saltwater**, but **poor resistance to acids and alkalis**.
- Biodegradable and environmentally friendly.

9. Color and Luster

- **Color:** White to pale yellow.
- **Luster:** Moderate, slightly glossy appearance.

10. Electrical Properties

- **Non-conductive** (poor electrical conductor).
- Accumulates static charge in dry environments.

4-6-Abaca Fiber (Manila Hemp)

Abaca fiber is obtained from the **leaf stalks** of the *Musa textilis* plant (a type of banana).

Grown mainly in the **Philippines** and **Ecuador**. Often called **Manila hemp**, but it's not real hemp.

Physical Properties:

- **Color:** Light brown to off-white.
- **Length:** 1.5–3 meters (long fiber).
- **Tensile strength:** 400–980 MPa (very high).
- **Moisture regain:** ~11%.
- **Specific gravity:** ~1.5 g/cm³.
- **Strong, flexible, and resistant to saltwater** → good for marine ropes and paper currency.

4-7-Henequen Fiber

Henequen comes from the **Agave fourcroydes** plant. It is similar to sisal and mainly grown in **Mexico** and **Central America**. Known as a “**sisal-type**” fiber.

Physical Properties:

- **Color:** Yellowish-white.
 - **Length:** 0.9–1.2 meters.
 - **Tensile strength:** 400–600 MPa.
 - **Moisture regain:** ~10%.
 - **Specific gravity:** ~1.45 g/cm³.
 - **Less flexible** than sisal but **good durability**.
 - Used for **ropes, twines, mats, and bags**.
-

4-8-Hemp Fiber

Hemp fiber is obtained from the **stalk** of the *Cannabis sativa* plant. One of the **oldest fibers known to humans**.

Physical Properties:

- **Color:** Yellowish-gray to dark brown.
- **Length:** 1–5 meters.
- **Tensile strength:** 550–900 MPa.

- **Moisture regains:** 12–14%.
- **Specific gravity:** $\sim 1.48 \text{ g/cm}^3$.
- **Strong, durable, and breathable.**
- **Used in textiles, ropes, canvas, and bio-composites.**
- **Resistant to mold, UV light, and saltwater.**

Questions

Q/ Multiple-Choice Questions (MCQs)

1. Sisal fibers are obtained from which plant?

- A) Cotton plant
- B) Agave sisalana
- C) Flax plant
- D) Jute plant

Answer: B) Agave sisalana

2. The color of sisal fibers is usually:

- A) Blue
- B) Creamy white to yellowish
- C) Dark brown
- D) Black

Answer: B) Creamy white to yellowish

3. The main use of sisal fibers is for:

- A) Clothing
- B) Ropes and mats
- C) Paper making
- D) Medical bandages

Answer: B) Ropes and mats

4. The tensile strength of sisal fibers is:

- A) 100–200 MPa
- B) 200–400 MPa
- C) 400–700 MPa

D) 700–1000 MPa

Answer: C) 400–700 MPa

5. Sisal fibers are mainly composed of:

A) Protein

B) Cellulose

C) Keratin

D) Nylon

Answer: B) Cellulose

6. The moisture regain of sisal fibers is about:

A) 2–4%

B) 10–12%

C) 18–20%

D) 25–30%

Answer: B) 10–12%

7. Sisal begins to decompose at approximately:

A) 100 °C

B) 150 °C

C) 220–250 °C

D) 300 °C

Answer: C) 220–250 °C

8. Sisal has:

A) High elasticity

B) Low elasticity

C) Very high flexibility

D) No strength

Answer: B) Low elasticity

9. Sisal fibers are resistant to:

A) Acid

B) Alkali

C) Saltwater

D) High heat

Answer: C) Saltwater

10. Sisal fiber is a type of:

A) Animal fiber

B) Synthetic fiber

C) Plant fiber

D) Mineral fiber

11. Abaca fiber is also known as:

A) Jute

B) Manila hemp

C) Coir

D) Flax

Answer: B) Manila hemp

12. Henequen fibers are obtained from which plant?

A) Agave fourcroydes

B) Musa textilis

C) Cannabis sativa

D) Agave sisalana

Answer: A) Agave fourcroydes

13. The strongest among abaca, henequen, and hemp fibers is usually:

A) Henequen

B) Abaca

C) Hemp

D) Sisal

Answer: C) Hemp

14. The moisture regain of hemp fibers is approximately:

A) 4%

B) 10%

C) 12–14%

D) 20%

Answer: C) 12–14%

15. Which of the following fibers is obtained from the stalk of the plant?

- A) Hemp
- B) Abaca
- C) Henequen
- D) Sisal

Answer: A) Hemp

16. The main use of abaca fibers is in:

- A) Clothing
- B) Currency paper and marine ropes
- C) Plastic composites
- D) Carpets

Answer: B) Currency paper and marine ropes

17. Henequen fibers have a specific gravity of about:

- A) 1.0
- B) 1.2
- C) 1.45
- D) 1.8

Answer: C) 1.45

18. Hemp fibers are resistant to:

- A) Acids
- B) UV light and mold
- C) Heat and fire
- D) Alkalis only

Answer: B) UV light and mold

19. Abaca fibers are extracted from:

- A) Stems
- B) Seeds
- C) Leaves
- D) Roots

Answer: C) Leaves

20. Henequen is most similar to:

- A) Jute
- B) Sisal
- C) Cotton
- D) Coir

Answer: B) Sisal

Answer: C) Plant fiber

Q/ True or False Questions

1. Sisal fibers are obtained from the stem of the plant.

False – They come from the leaves of *Agave sisalana*.

2. Sisal fibers are biodegradable.

True

3. Sisal fibers have high elasticity.

False – They have low elasticity.

4. Sisal is resistant to saltwater.

True

5. Sisal fibers melt when heated.

False – They decompose but do not melt.

6. Sisal is used in making ropes and mats.

True

7. Sisal fibers are synthetic.

False – They are natural plant fibers.

8. Abaca is obtained from the stem of the plant.

False – It comes from the **leaf stalks**.

9. Henequen and sisal are both Agave fibers.

✓ True

10. Hemp is a synthetic fiber.

✗ False – It is a **natural plant fiber**.

11. Hemp fibers have good resistance to UV light.

✓ True

12. Abaca is mainly used for making clothes.

✗ False – It is used for **ropes, mats, and paper**.

13. Henequen fibers are longer than hemp fibers.

✗ False – Hemp fibers are generally longer.

14. All three fibers are biodegradable.

✓ True

4. Short Answer / Enumeration Questions

1. List **three main uses** of sisal fibers.

✓ Ropes, mats, brushes (also carpets, handicrafts, composite reinforcement).

2. Mention **three main physical properties** of sisal fibers.

✓ High tensile strength, low elasticity, moderate moisture absorption.

3. Write **two advantages** of sisal fibers.

✓ Biodegradable and eco-friendly; good saltwater resistance.

4. Write **two disadvantages** of sisal fibers.

✓ Low elasticity; poor resistance to acids and alkalis.

5. What is the **moisture regaining percentage** of sisal fibers?

✓ About 10–12%.

6. List the **three plant sources** of Abaca, Henequen, and Hemp.

- ✓ Abaca – *Musa textilis*
- ✓ Henequen – *Agave fourcroydes*
- ✓ Hemp – *Cannabis sativa*

7. Mention **two main uses** of each fiber.

- ✓ Abaca: ropes, currency paper
- ✓ Henequen: mats, twines
- ✓ Hemp: textiles, composites

8. Write **two advantages** of hemp fiber.

- ✓ High strength and durability; resistant to UV and mildew.

9. Write **two disadvantages** of Abaca fiber.

- ✓ Coarse texture; limited flexibility.

10. What is the **moisture regain** of Henequen fiber?

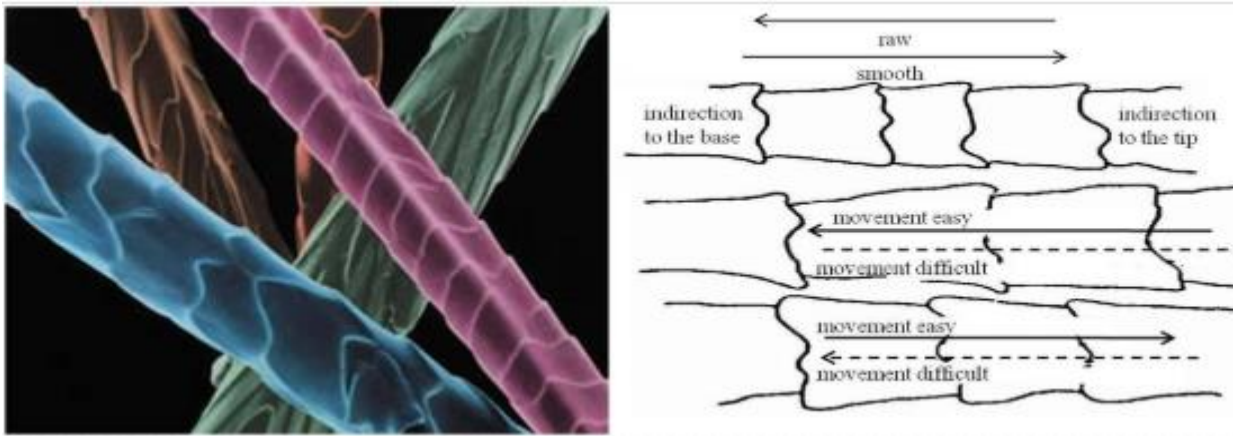
- ✓ About 10%.

Chapter Five Animal Fibers

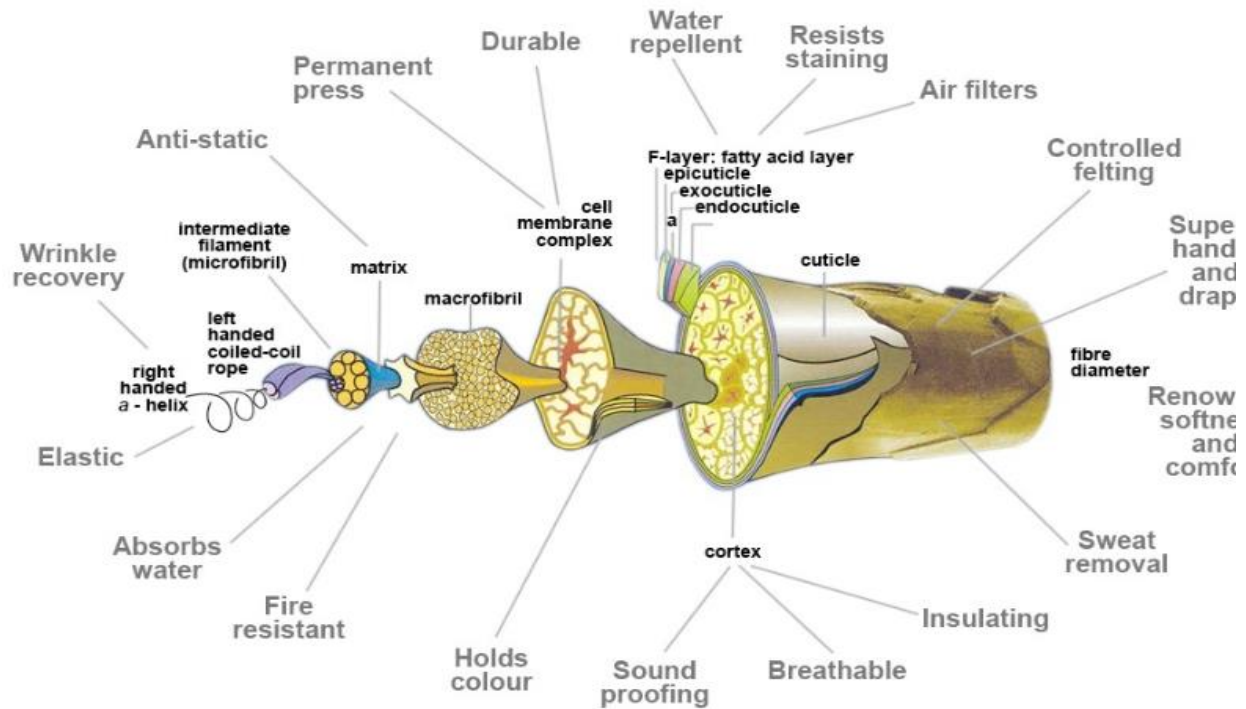
5-1-What is wool

Animal fibers are natural textile fibers derived from animals, composed primarily of proteins. These fibers come from a variety of sources, including the hair, fur, or secretions of different animals. Among the most common and versatile of these is wool, prized for its warmth, durability, and insulating properties.

Wool is the textile fiber obtained from the fleece of sheep and other animals such as goats (cashmere and mohair), rabbits (angora), and camelids (alpaca, llama, and camel hair). The structure of wool fibers, with their characteristic crimp or wave, creates tiny air pockets that provide excellent insulation, making it a popular choice for clothing, blankets, and carpets.



Fiber surface



Names of fiber regions

5-2-From Fleece to Fabric: The Production of Wool

The journey of wool from a sheep's back to a finished product involves several key stages:

- **Shearing:** The process begins with the shearing of a sheep's fleece, which is typically done once a year.
- **Cleaning and Scouring:** The raw wool is then cleaned to remove dirt, grease (lanolin), and other impurities. Lanolin, a valuable byproduct, is often used in cosmetics and skin care products.
- **Carding:** After cleaning, the wool fibers are passed through a series of metal teeth in a process called carding. This disentangles the fibers and aligns them into a continuous web.
- **Spinning:** The carded wool is then spun into yarn. The thickness of the yarn can be varied depending on the intended use.

- **Weaving and Knitting:** Finally, the woolen yarn is woven or knitted into fabric, which can then be used to create a wide array of products.

5-2-The Remarkable Properties of Wool

Wool is a highly sought-after material due to its unique combination of properties:

- **Insulation:** The natural crimp of wool fibers traps air, providing excellent insulation against both cold and heat.
- **Durability and Elasticity:** Wool fibers can be bent thousands of times without breaking and can stretch and return to their original shape, making woolen garments long-lasting.
- **Moisture Wicking:** Wool can absorb a significant amount of moisture without feeling wet, drawing perspiration away from the body to keep the wearer comfortable.
- **Flame Resistance:** Wool is naturally flame-resistant and will often self-extinguish when the source of the flame is removed.
- **Biodegradable and Renewable:** As a natural fiber, wool is a renewable resource that is biodegradable.

5-3-A Multitude of Uses

The versatility of wool lends itself to a wide range of applications, including:

- **Apparel:** From fine suits and soft sweaters to durable outerwear, wool is a staple in the fashion industry.
- **Home Furnishings:** Its durability and flame resistance make it an ideal choice for carpets, upholstery, and blankets.
- **Industrial Applications:** Wool is also used for insulation in buildings and as a component in mattresses and other furnishings.
- **Innovative Uses:** More recently, wool has found use in unconventional applications such as garden mulch and as a material for soundproofing.

Beyond wool, other notable animal fibers include the luxurious softness of **cashmere** from the Cashmere goat, the silky sheen of **mohair** from the Angora goat, and the fine, warm fleece of the **alpaca**. **Silk**, another prominent animal fiber, is unique in that it is a filament fiber produced by silkworms. Each of these fibers possesses its own distinct characteristics, contributing to the rich diversity of natural textiles available.

5-4-Physical properties of wool fiber

1. Appearance and Structure

- **Color:** Usually creamy white to yellowish, but may vary depending on breed and processing.
- **Luster:** Has a natural sheen (soft, not glossy).
- **Crimp:** Wool fibers are naturally wavy or crimped, which increases elasticity and bulk.
- **Cross-section:** Generally oval or circular, with a scaly surface structure.

2. Density

- **Specific gravity:** About **1.30 – 1.32**.
- This means wool is **lighter than cotton** and heavier than synthetic fibers like acrylic.

3. Moisture Absorption

- Wool is **hygroscopic**, meaning it absorbs moisture from the air.
- **Moisture regains:** Around **14–18%** at standard conditions (65% RH, 20°C).
- It can absorb up to **30% of its weight** in water without feeling wet.
- This gives wool **excellent comfort** and **temperature regulation**.

4. Thermal Properties

- Wool is a **good thermal insulator** because of the air trapped in its crimped structure.
- It keeps the wearer **warm in cold weather** and **cool in warm weather**.
- Wool is **flame-resistant** — it does not melt and is difficult to ignite.

5. Elasticity and Resilience

- Wool has **high elasticity** — it can stretch up to **25–30%** of its original length and recover well.
- This makes wool fabrics **resistant to wrinkling** and **able to retain shape**.

6. Tensile Strength

- **Dry strength:** 1.0–1.7 g/denier
- **Wet strength:** Decreases by about 25%.
- Wool is **weaker when wet** compared to most other natural fibers.

7. Abrasion Resistance

- Moderate to good.
- The scaly surface may cause **felting** during agitation (especially in water and heat).

8. Electrical Properties

- Wool has **high electrical resistance** when dry, so it tends to **accumulate static electricity**, though its moisture absorption helps reduce static buildup.

9. Dimensional Stability

- Wool can **shrink** due to felting and relaxation shrinkage, especially if not treated (e.g., Superwash process).

10. Thermal Decomposition Begins to decompose around **100–120 °C** due to protein breakdown.

- It chars rather than melts.

5-5-Silk fibers

Silk fibers are **natural protein fibers** produced by silkworms, most commonly from the species *Bombyx mori*. These fibers are among the **strongest and most luxurious natural fibers**, widely used in textiles for their luster, softness, and strength.

Composition and Structure

- **Main component:** *Fibroin* (a protein secreted by the silkworm)
- **Outer coating:** *Sericin* (a gummy substance that holds the fibroin filaments together)
- **Molecular structure:** Long chains of amino acids (mostly glycine, alanine, and serine), forming crystalline regions that provide **high tensile strength** and **elasticity**.

Source and Production

1. Silkworms feed on **mulberry leaves**.
2. They spin **cocoons** made of continuous silk filaments.
3. The cocoons are boiled to remove sericin and unwind the filament (known as *reeling*).
4. The filament is then twisted into threads for weaving.

Properties

Property	Description
Type	Natural protein fiber
Appearance	Smooth, shiny, and soft
Strength	Very strong (comparable to steel by weight)
Elasticity	Moderate – returns to shape easily
Absorbency	High – comfortable in hot and cold weather
Thermal behavior	Good insulation; loses strength when wet
Chemical resistance	Sensitive to alkalis and sunlight
Burning behavior	Burns slowly, smells like burning hair

Uses

- Luxury fabrics (sarees, ties, dresses, scarves)
- Upholstery and draperies
- Medical sutures (because it is biocompatible)
- Composite materials and parachutes (historically)

Advantages

- Soft, smooth texture

- Strong yet lightweight
- Excellent drape and shine
- Comfortable against skin

Disadvantages

- Expensive production
- Weak when wet
- Damaged by sunlight, sweat, and insects
- Requires delicate care (dry cleaning or gentle washing)

Questions

1. What are animal fibers primarily composed of?
2. Which animal is the most common source of wool?
3. Can you name three other animals besides sheep that produce wool or hair used for textiles?
4. What is the name of the process of removing a sheep's fleece?
5. What valuable byproduct is removed from raw wool during the cleaning process?
6. What is the purpose of "carding" in wool production?
7. How does the "crimp" in wool fibers help to keep you warm?
8. Why is wool considered a durable and elastic fiber?
9. What does it mean that wool can "wick" moisture? How is this beneficial in clothing?
10. Besides clothing, what are two other common uses for wool in the home?
11. Why is wool considered a naturally flame-resistant material?
12. Is wool a renewable resource? Why or why not?

Comparative and Analytical Questions

13. How is silk different from wool in terms of its origin (how it's produced by the animal)?
14. Compare wool to another animal fiber mentioned in the text, such as cashmere or alpaca. What do you think makes one more "luxurious" than the other?

15. Why might someone choose a woolen carpet over one made from synthetic (man-made) fibers?
16. The text mentions "innovative uses" for wool like garden mulch. Why do you think wool would be effective for this purpose?
17. What do you think are the biggest challenges in the process of turning fleece into a finished fabric?

Multiple-Choice Questions

1. What is the specific gravity of wool fibers?

- A) 0.9 – 1.0
- B) 1.30 – 1.32
- C) 1.45 – 1.50
- D) 1.10 – 1.15

Answer: B) 1.30 – 1.32

2. The natural crimp in wool fibers helps to:

- A) Increase fiber strength
- B) Increase elasticity and bulk
- C) Decrease moisture absorption
- D) Improve color brightness

Answer: B) Increase elasticity and bulk

3. Wool can absorb up to _____ of its weight in water without feeling wet.

- A) 10%
- B) 20%
- C) 30%

D) 50%

Answer: C) 30%

4. Which of the following statements about wool is TRUE?

- A) Wool melts easily when heated.
- B) Wool is hydrophobic and repels water.
- C) Wool is flame-resistant and does not melt.
- D) Wool is stronger when wet.

Answer: C) Wool is flame-resistant and does not melt.

5. The natural luster of wool is described as:

- A) Glossy and shiny
- B) Soft and subdued
- C) Metallic
- D) Dull and rough

Answer: B) Soft and subdued

6. Wool has high elasticity, which makes it:

- A) Easily wrinkled
- B) Unable to stretch
- C) Resistant to wrinkling and able to retain shape
- D) Brittle when stretched

Answer: C) Resistant to wrinkling and able to retain shape

7. When wet, the tensile strength of wool fibers:

- A) Increases by 50%
- B) Remains the same
- C) Decreases by about 25%

D) Disappears completely

Answer: C) Decreases by about 25%

8. Wool tends to accumulate static electricity because:

A) It has a smooth surface

B) It has high electrical resistance when dry

C) It absorbs too much water

D) It is made of cellulose

Answer: B) It has high electrical resistance when dry

9. Wool shrinkage is mainly caused by:

A) UV exposure

B) Felting during washing

C) Dry heat

D) Chemical bleaching

Answer: B) Felting during washing

10. Thermal decomposition of wool begins around:

A) 60–80 °C

B) 90–100 °C

C) 100–120 °C

D) 150–200 °C

Answer: C) 100–120 °C

Fill-in-the-Blank Questions (Silk Fibers)

1. Silk is a _____ fiber obtained from the cocoon of the silkworm.
2. The main protein in silk is called _____.
3. The sticky substance surrounding silk fiber is known as _____.
4. Silk fibers are mainly produced by the insect _____.
5. The process of removing sericin from raw silk is called _____.

6. Silk fibers have a natural _____ and smooth texture.
7. Silk is damaged by strong _____ and exposure to _____.
8. Silk burns slowly and gives off a smell similar to burning _____.
9. Silk is composed mainly of the amino acids _____, _____, and _____.
10. Silk is highly _____, making it comfortable in both warm and cool weather.

Comparison: Silk vs Wool Fibers

Property	Silk	Wool
Source	Animal fiber from silkworm cocoon	Animal fiber from sheep fleece
Main Protein	Fibroin	Keratin
Texture	Smooth, soft, and shiny	Crimped, coarse, and dull
Elasticity	Moderate	High (returns to shape easily)
Luster	Natural sheen	Usually, matte
Warmth	Moderate warmth	Excellent warmth (good insulator)
Strength	Very strong (especially when dry)	Weaker when wet, elastic strength
Moisture Absorption	High	Very high
Reaction to Heat	Shrinks and turns yellow	Shrinks (felting)
Burning Smell	Burning hair	Burning hair (similar)
Cost	Expensive	Less expensive
Care	Needs gentle care (dry clean)	Easy to wash carefully

Chapter Six

6-1- Viscose Rayon

Introduction

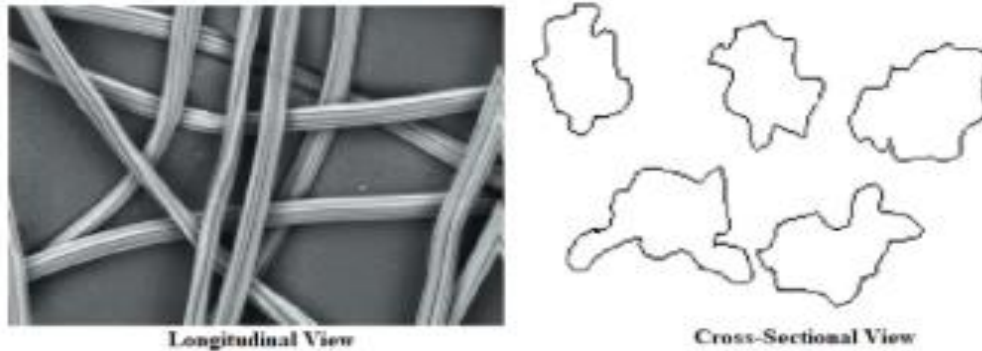
Man-made fibers are those that are **not found naturally** in plants or animals but are **produced artificially** by humans through chemical or mechanical processes. Rayon and viscose are examples of **regenerated cellulosic fibers**, which means they are **made from natural cellulose** (usually from wood pulp or cotton linters) but are **chemically processed** to form fibers.

6-2- Source of Rayon (Viscose)

- The **main raw material** for rayon is **cellulose**, obtained from:
 - **Wood pulp** (from trees such as pine, beech, or bamboo)
 - **Cotton linters** (short fibers left on cotton seeds after ginning)
- The cellulose is dissolved in chemicals to form a **viscous solution** called **viscose**, which is then forced through fine holes called **spinnerets** to form long continuous filaments of rayon.

6-3- Structure of Rayon (Viscose)

- **Chemical structure:** Rayon has the same basic structure as natural cellulose ($C_6H_{10}O_5$)_n, but it is **regenerated** through a chemical process.
- The long-chain cellulose molecules are reformed into fine, smooth fibers.
- The structure is **semi-crystalline**, containing both crystalline and amorphous regions, which gives rayon:
 - High absorbency
 - Softness
 - Good drape
 - Smooth and silky appearance
- Rayon fibers are **straight, smooth, and shiny**, without natural crimp like wool or cotton.



Structure of Viscose Rayon

6-4- Properties of Rayon/Viscose

- Soft and comfortable like cotton.
- Highly absorbent, easy to dye.
- Poor elasticity (wrinkles easily).
- Loses strength when wet.
- Feels cool to wear, good for warm climates.
- Blends well with cotton or polyester to improve strength and wrinkle resistance.

6-4-1 Physical Properties of Viscose Rayon

1. **Appearance:**
 - Smooth, soft, and silk-like in luster and feel.
 - Transparent and bright (artificial silk appearance).
2. **Length and Fineness:**
 - Manufactured in both filament and staple fiber form.
 - Fineness can be controlled during production.
3. **Strength:**
 - Moderate strength when dry.
 - Loses about 40–70% of its strength when wet.
 - Tenacity (dry): 2.0–2.6 g/dtex; (wet): 1.1–1.5 g/dtex.
4. **Elasticity:**
 - Poor elasticity; wrinkles easily and doesn't recover well from deformation.
5. **Absorbency:**
 - Highly absorbent (better than cotton).

- Regains moisture easily; very comfortable to wear.
- 6. **Thermal Behavior:**
 - Burns like paper; cannot withstand very high temperatures.

Starts to decompose around 150–200°C.

- 7. **Density:**
 - About 1.5 g/cm³ (similar to cotton).
- 8. **Drapability:**
 - Excellent drape and soft hand feel — used widely in apparel and upholstery.
- 9. **Dimensional Stability:**
 - Poor; tends to shrink when wet.
- 10. **Luster:**
 - Can be controlled during spinning (from dull to bright).

6-4-2-Chemical Properties of Viscose Rayon

- 1. **Composition:**
 - Regenerated cellulose (C₆H₁₀O₅)_n.
 - Chemically similar to natural cellulose (cotton).
- 2. **Action of Acids:**
 - Strong acids (like H₂SO₄) destroy the fiber quickly.
 - Weak acids have mild effects.
- 3. **Action of Alkalis:**
 - Resistant to weak alkalis (like soap, mild NaOH).
 - Strong alkalis cause swelling and loss of strength.
- 4. **Effect of Bleaches:**
 - Can be safely bleached with mild oxidizing agents (e.g., hydrogen peroxide).
 - Chlorine bleaches may weaken the fiber if not properly controlled.
- 5. **Effect of Solvents:**
 - Insoluble in most organic solvents.
- 6. **Effect of Sunlight:**
 - Prolonged exposure weakens the fiber and causes yellowing.
- 7. **Dye Affinity:**
 - Very high; dyes evenly and brightly with a wide range of dyes (especially direct and vat dyes).
- 8. **Effect of Microorganisms:**

- Susceptible to mildew and bacteria in damp conditions.
9. **Effect of Heat:**
- Scorches easily; cannot withstand ironing at high temperatures.

6-5- Uses of Rayon

- Apparel: dresses, blouses, linings, and ties.
- Home textiles: curtains, upholstery, and bed sheets.
- Industrial use: tire cords, medical bandages, and nonwoven fabrics.

6-6- Manufacture of Viscose Rayon

The production of viscose rayon involves several chemical and physical steps:

Step 1 – Steeping

- **Cellulose pulp** (usually wood pulp or cotton linters) is steeped in **sodium hydroxide (NaOH)** solution.
- This converts the cellulose into **alkali cellulose**.

Reaction:

Cellulose + NaOH → Alkali cellulose

Step 2 – Pressing

- The excess NaOH solution is **pressed out**, and the solid alkali cellulose is **crumbled** into small pieces to increase surface area.

Step 3 – Aging

- The crumbled alkali cellulose is **aged** (exposed to air) for a certain period.
- During aging, the molecular chains are **partially broken down**, improving spinning quality.

Step 4 – Xanthation

- The aged alkali cellulose is treated with **carbon disulfide (CS₂)** to form **cellulose xanthate**, which is an orange-colored compound.

Reaction:

Alkali cellulose + CS₂ → Cellulose xanthate

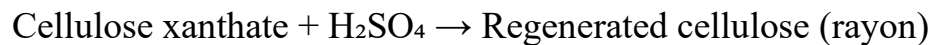
Step 5 – Dissolving

- The cellulose xanthate is dissolved in a **dilute sodium hydroxide** solution to make a **thick viscous liquid** called **viscose**.
- This solution is stored for a few hours to remove air bubbles and mature.

Step 6 – Spinning

- The viscose solution is **pumped through spinnerets** (fine holes) into a **spinning bath** containing **sulfuric acid (H₂SO₄)** and other salts.
- In the acid bath, **regeneration of cellulose** occurs — fibers solidify and are formed as continuous filaments.

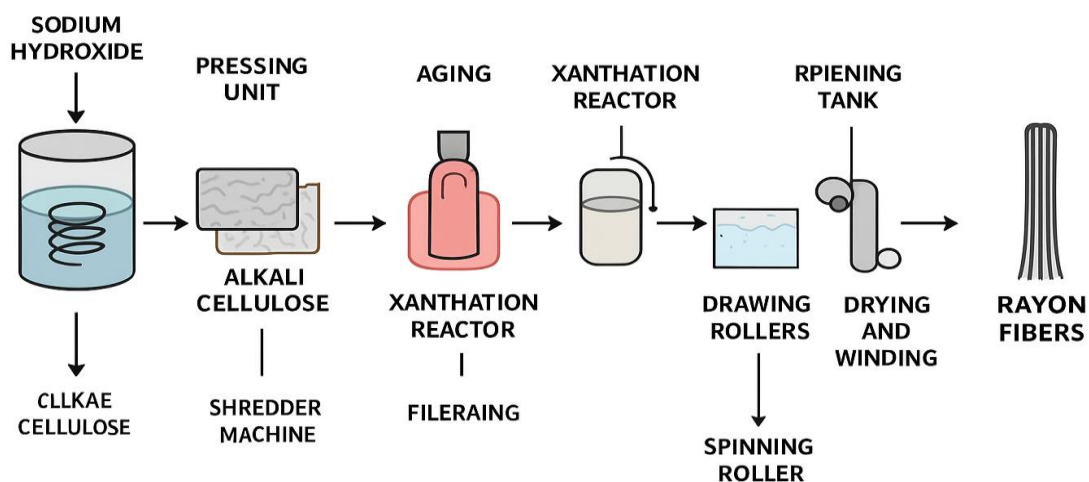
Reaction:



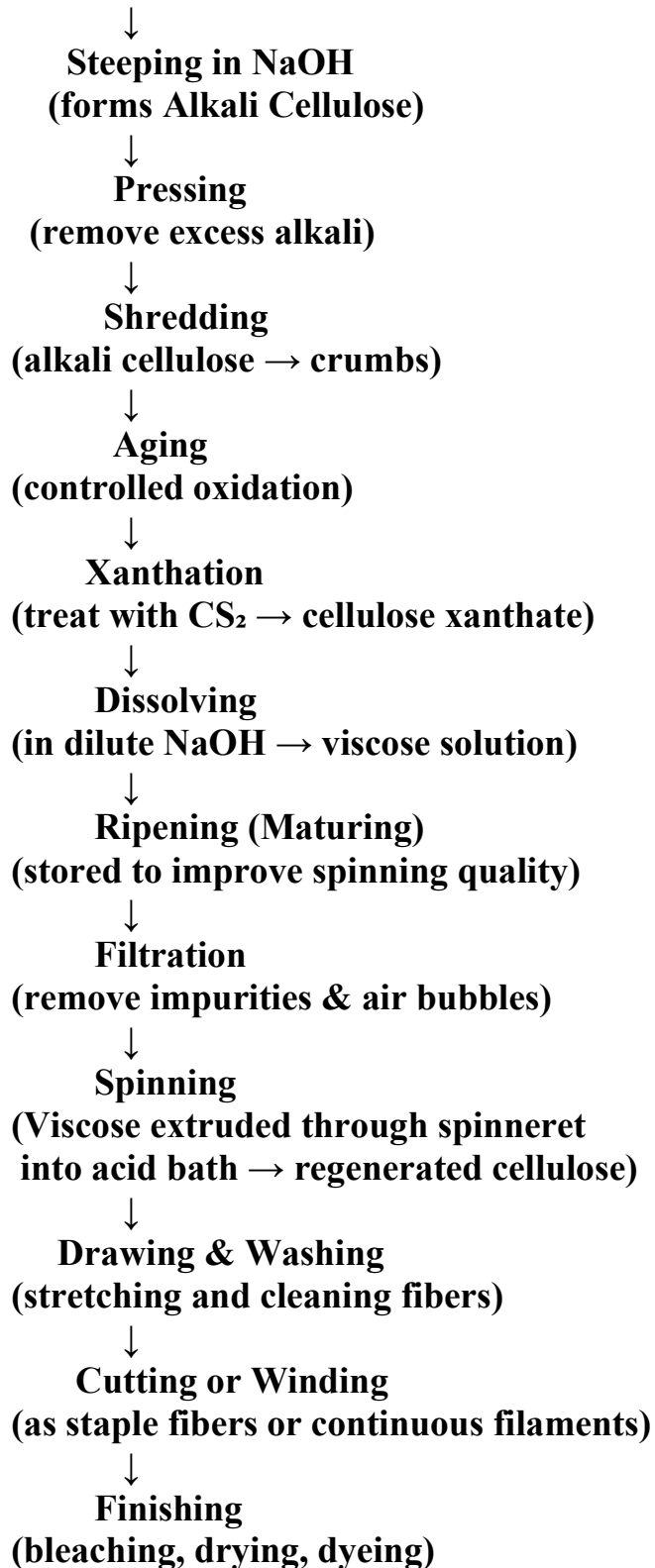
Step 7 – Washing and Finishing

- The fibers are **washed** to remove acid and impurities.
- Then they are **stretched, dried, and wound** onto bobbins.
- Finally, the fibers may be **bleached or dyed** for use in textiles.

MANUFACTURE OF VISCOSE RAYON



Manufacture of viscose rayon

**6-7-Process Flow Chart of Viscose Rayon Production
Wood Pulp or Cotton Linters**

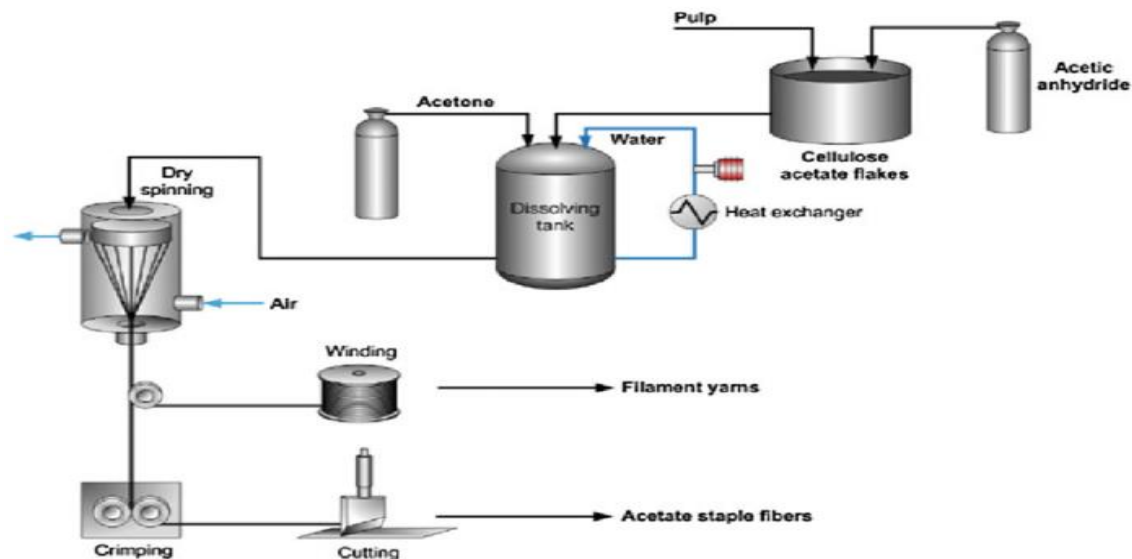
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Final Rayon Fiber

6-8- Acetate fibers

Acetate fibers are a type of **semi-synthetic fiber** made from **cellulose**, typically derived from wood pulp, and **chemically modified** using **acetic acid**. They are one of the first man-made fibers, developed in the early 20th century, and are considered part of the **cellulose acetate** family.

6-9-Composition and Production

- **Source:** Natural cellulose (from cotton linters or wood pulp)
- **Chemical Process:**
 1. Cellulose is treated with **acetic acid**, **acetic anhydride**, and **sulfuric acid**.
 2. This produces **cellulose acetate**, which is then dissolved in a solvent (like acetone).
 3. The solution is extruded through spinnerets to form fibers.
 4. The solvent is evaporated, leaving solid acetate fibers.



Schematic diagram of acetate rayon manufacturing process

6-10- Properties of Acetate Fibers

- **Appearance:** Silky, lustrous, smooth
- **Feel:** Soft, drapes well
- **Color:** Can be dyed easily; holds color well
- **Lightweight:** Good for delicate garments
- **Thermoplastic:** Can melt or deform with heat (careful with ironing!)
- **Moisture-resistant:** Low absorbency
- **Weak when wet:** Loses strength when wet, prone to shrinkage

6-11-Common Uses

- **Fashion:**
 - Lining for jackets, suits, and dresses
 - Evening wear and bridal gowns
- **Home textiles:**
 - Curtains and upholstery
- **Cigarette filters:** Made from **cellulose acetate tow**

6-12- Care Considerations

- **Avoid high heat:** Can melt or distort
- **Dry clean preferred:** Some garments may be washable, but care is needed
- **Low resistance to abrasion:** Prone to pilling and snagging

6-13- Acetate vs. Other Fibers

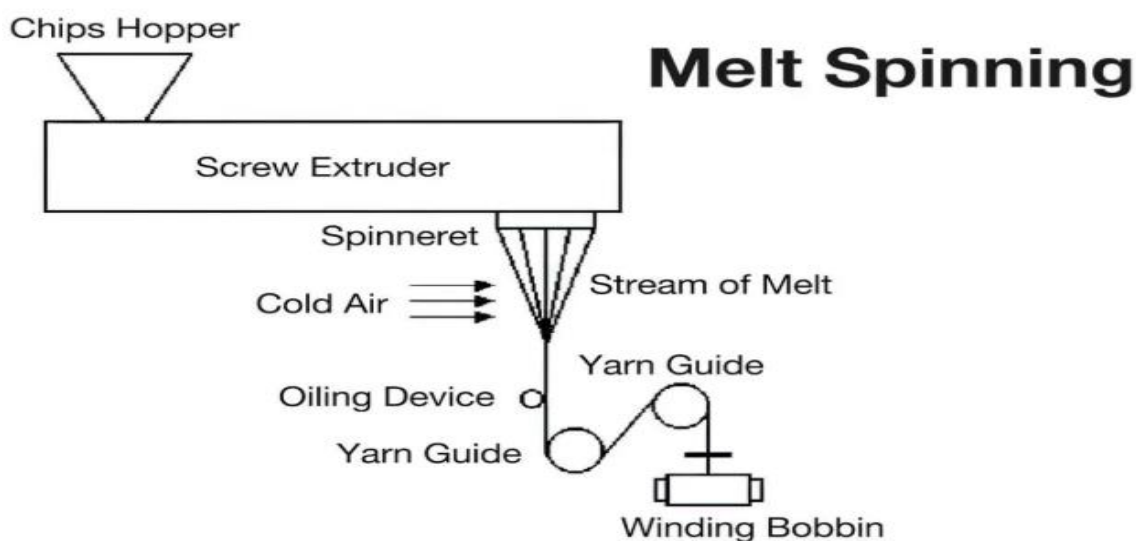
Feature	Acetate	Polyester	Rayon
Origin	Semi-synthetic	Synthetic	Semi-synthetic
Feel	Silky, soft	Smooth, varies	Soft, cotton-like
Moisture Wicking	Low	Low	Moderate
Heat Resistance	Low	High	Low
Durability	Moderate (low wet strength)	High	Moderate

6-14-Polyester Fibers

Polyester fibers are one of the most commonly used synthetic fibers, made from a polymer called polyethylene terephthalate (PET), which is derived from petroleum-based products. Polyester is known for its versatility, durability, and wide range of applications across industries, particularly in textiles.

Composition and Production

- **Source:** Synthetic polymer (PET) produced from petroleum-based chemicals.
- **Chemical Process:**
 1. Terephthalic acid and ethylene glycol are chemically reacted to form a polymer chain (PET).
 2. The polymer is then melted and extruded through spinnerets to form long continuous filaments or fibers.
 3. These fibers are cooled, stretched, and sometimes textured to increase their strength and elasticity.



Flow chart of manufacturing process of Polyester

Properties of Polyester Fibers

- **Appearance:** Smooth, lustrous, and can be made to mimic natural fibers like cotton or silk.

- **Feel:** Slightly stiff but softens with use and treatment.
- **Color:** Highly colorfast, can be easily dyed in a variety of colors.
- **Strength:** Very strong, even when wet, and resists abrasion.
- **Durability:** Resistant to stretching, shrinking, and wrinkles; maintains its shape well.
- **Moisture-resistant:** Low moisture absorbency, which makes it quick-drying.
- **Thermal Insulation:** Has low thermal conductivity, which can provide warmth, but doesn't "breathe" like natural fibers.
- **Elasticity:** Retains its shape after stretching and is resistant to wrinkling.

Common Uses

- **Fashion:**
 - Casual wear, formal wear, and evening gowns
 - Activewear and sportswear due to its durability and moisture-wicking properties
 - Blended with other fibers (like cotton, wool, or spandex) to improve performance and comfort
- **Home Furnishings:**
 - Upholstery, curtains, and bedding
 - Carpet fibers, especially for high-traffic areas
- **Industrial Applications:**
 - Reinforcement in composite materials
 - Automotive fabrics and geotextiles

Polyester is favored for its strength, low cost, and wide range of applications. Its resilience against environmental factors like sunlight and moisture makes it particularly suitable for outdoor gear and upholstery. However, its low breathability and tendency to retain odors may make it less ideal for certain uses compared to natural fibers.

6-15-Nylon Fibers

Nylon fibers are a type of synthetic fiber made from polyamides, which are polymers formed by the reaction of diamines and dicarboxylic acids. Nylon was one of the first synthetic fibers developed and is still widely used due to its exceptional strength, versatility, and durability.

Composition and Production

Source: Made from petroleum-based chemicals, primarily hexamethylene diamine and adipic acid.

Chemical Process:

1. Hexamethylene diamine and adipic acid are reacted together to form nylon 6,6 (one of the most common types of nylon).
2. The resulting polymer undergoes a process called **polycondensation**, where the polymer chains are built up and water molecules are released.
3. The polymer is then melted and extruded through spinnerets to form long fibers.
4. The fibers are cooled, stretched, and sometimes textured to improve strength and elasticity.

Properties of Nylon Fibers

- **Appearance:** Smooth and shiny, often resembling silk.
- **Feel:** Soft and silky to the touch, though slightly stiffer than natural fibers.
- **Strength:** Very strong and durable, one of the strongest synthetic fibers, and resistant to abrasion.
- **Elasticity:** Highly elastic, which makes it resistant to wrinkles and retains shape well after stretching.
- **Moisture Resistance:** Nylon fibers have moderate moisture absorbency, meaning they can take in some moisture, but they dry quickly.
- **Thermal Properties:** Nylon fibers are heat-resistant to some degree but can melt at higher temperatures, which means care is needed during ironing.
- **Chemical Resistance:** Nylon is resistant to many chemicals, oils, and greases, but can degrade when exposed to acids or bleach.

Common Uses

- **Fashion:**
 - Stockings, hosiery, and lingerie (Nylon was originally developed for stockings).
 - Outerwear, such as jackets, coats, and activewear.
 - Sportswear and swimwear due to its strength, flexibility, and moisture-wicking properties.
- **Home Furnishings:**
 - Carpets and rugs, especially those used in high-traffic areas, as it resists wear and tear.

- Upholstery and curtains, known for its durability.
- **Industrial and Technical Applications:**
 - Ropes, cords, and industrial fabrics, as nylon's strength makes it ideal for these uses.
 - Reinforcement in composite materials, like those used in automotive and aerospace industries.
 - Fishing lines, parachutes, and medical sutures, owing to its toughness and flexibility.
- **Automotive:**
 - Used in the production of parts such as airbags, fuel lines, and various engine components due to its heat resistance and strength.

Nylon's ability to be lightweight, strong, and resistant to wear and tear makes it ideal for a wide range of applications, from fashion to industrial uses. Its versatility, combined with its durability and resistance to moisture and chemicals, ensures its continued popularity. However, it is not biodegradable and can take years to break down in the environment, leading to concerns about sustainability.

Terylene Fibers (Polyester)

Terylene is a brand name for a type of **polyester fiber**, which is made from **polyethylene terephthalate (PET)**. It's one of the most common types of polyester used in textiles and has almost identical properties to polyester fibers.

Composition and Production

- **Source:** Derived from petroleum-based products, specifically **terephthalic acid** and **ethylene glycol**.
- **Chemical Process:**
 1. The chemicals terephthalic acid and ethylene glycol undergo a process called **polycondensation** to form a polymer chain called **polyethylene terephthalate (PET)**.
 2. The PET polymer is melted and extruded through spinnerets, where it forms continuous filaments or fibers.
 3. These fibers are cooled, stretched, and sometimes textured to enhance their strength, elasticity, and appearance.

Properties of Terylene (Polyester) Fibers

- **Appearance:** Smooth, shiny, and can be made to mimic natural fibers like cotton, silk, or wool.

- **Feel:** Initially stiff, but softens with wear. It is relatively lightweight.
- **Strength:** Extremely strong, with excellent resistance to abrasion and wear.
- **Elasticity:** Retains its shape well and is highly resistant to wrinkles.
- **Moisture Resistance:** Low absorbency, dries quickly.
- **Durability:** Resistant to stretching, shrinking, and fading. Retains its shape and strength over time.
- **Thermal Resistance:** Can withstand heat but may melt at high temperatures (requires care when ironing).

Common Uses of Terylene (Polyester)

- **Fashion:** Used in clothing like shirts, suits, dresses, skirts, and sportswear. Also commonly blended with natural fibers (like cotton or wool) to improve durability and reduce cost.
- **Home Furnishings:** Curtains, upholstery, bed linens, and carpets.
- **Industrial Uses:** Reinforcement in composites, automotive fabrics, and geotextiles.
- **Outdoor Gear:** Used in tents, jackets, and other gear due to its weather resistance and durability.

Acrylic Fibers

Acrylic fibers are synthetic fibers made from **polyacrylonitrile (PAN)**, a polymer that is derived from **acrylonitrile**, a petrochemical compound.

Composition and Production

- **Source:** Made from **acrylonitrile**, which is derived from petroleum.
- **Chemical Process:**
 1. **Acrylonitrile** is polymerized to form **polyacrylonitrile (PAN)**.
 2. The PAN polymer is then dissolved in a solvent and extruded through spinnerets to form fibers.
 3. The fibers are coagulated in a solution (such as water) to form solid strands, which are then dried and stretched to increase strength.

Properties of Acrylic Fibers

- **Appearance:** Soft and fluffy, with a wool-like texture. It has a slight sheen but isn't as shiny as nylon or polyester.
- **Feel:** Warm and lightweight, often compared to wool, which makes it ideal for winter clothing.

- **Strength:** Strong, but not as strong as nylon. Can be damaged by abrasion and may break more easily under stress.
- **Elasticity:** Retains shape well and is resistant to wrinkling.
- **Moisture Absorption:** Low absorbency, making it dry quickly.
- **Durability:** Resistant to mildew, rot, and sunlight. However, it can degrade under harsh chemical conditions.
- **Thermal Properties:** Good thermal insulation, which makes it a popular alternative to wool in colder climates.

Common Uses of Acrylic Fibers

- **Fashion:**
 - Sweaters, scarves, hats, and gloves (often used as a wool substitute due to its softness and warmth).
 - Outdoor and sportswear, particularly cold-weather gear.
 - Blankets and shawls.
- **Home Furnishings:**
 - Carpets, upholstery fabrics, and curtains.
 - Bedspreads and blankets, especially those requiring warmth without the weight of wool.
- **Industrial Uses:**
 - Used in some industrial fabrics, such as those found in automotive interiors or geotextiles.

Environmental Considerations:

Acrylic fibers, like other synthetic fibers, are not biodegradable, which can lead to concerns about their environmental impact when they are discarded. However, they are more resistant to environmental factors like mildew and sunlight compared to other fibers, which increases their longevity.

Comparison of Terylene (Polyester) and Acrylic Fibers

- **Appearance:** Terylene (polyester) tends to be shinier and smoother, whereas acrylic fibers have a softer, wool-like appearance.
- **Feel:** Acrylic fibers mimic wool more closely in terms of warmth and softness, while Terylene (polyester) is often more rigid and cool to the touch.
- **Strength:** Terylene (polyester) is generally stronger and more durable, whereas acrylic fibers are lighter and less strong.

- **Durability:** Terylene (polyester) resists abrasion, fading, and shrinking better than acrylic fibers, which can degrade more easily.
- **Moisture Resistance:** Both fibers are resistant to moisture, but Terylene (polyester) has even lower absorbency, making it quicker to dry than acrylic.
- **Thermal Insulation:** Acrylic fibers offer better warmth retention, often used as a wool substitute for cold-weather garments.

Both fibers are incredibly versatile, but their specific uses depend on the desired characteristics of the final product—whether it’s warmth, strength, resistance to wear, or the ability to mimic natural fibers like wool or silk.

True/False Questions

1. **True or False:** Acetate fibers are made from cellulose chemically modified with acetic acid.
2. **True or False:** Polyester fibers are insoluble in water.
3. **True or False:** Nylon fibers are weak when exposed to heat.
4. **True or False:** Acrylic fibers can mimic wool and are used as a wool substitute in winter clothing.
5. **True or False:** Terylene fibers are a type of polyester and are difficult to clean.
6. **True or False:** Nylon fibers are very strong but can easily be affected by moisture.
7. **True or False:** Acetate fibers are heat-resistant and can be washed in hot water.
8. **True or False:** Polyester fibers are harder to dye compared to acetate or acrylic fibers.

Comparison Questions

1. Compare acetate and polyester fibers in terms of moisture absorption and water resistance.
2. How do acrylic fibers differ from nylon in terms of thermal insulation?
3. What is the difference between terylene (polyester) and acetate in appearance and clothing applications?
4. Is acrylic more resistant to UV light than nylon? Explain why.
5. Compare acrylic and polyester fibers in terms of strength, durability, and longevity.
6. What are the main differences between acetate and nylon in clothing applications?

7. How do the thermal properties of acetate and nylon affect their use in fashion?
8. Compare polyester and acrylic fibers in their ability to retain color after repeated washing.

Multiple-Choice Questions

1. **What is the main raw material used to produce acetate fibers?**
 - A. Acetic acid
 - B. Polyethylene
 - C. Cellulose
 - D. Acrylic
2. **Which fiber has the highest heat resistance?**
 - A. Acrylic
 - B. Acetate
 - C. Nylon
 - D. Polyester
3. **Which fiber can resemble natural wool?**
 - A. Acrylic
 - B. Polyester
 - C. Nylon
 - D. Acetate
4. **Which fiber is most resistant to tearing and abrasion?**
 - A. Nylon
 - B. Acrylic
 - C. Acetate
 - D. Terylene (Polyester)
5. **Which fiber requires special care in washing because it can deform under high temperatures?**
 - A. Acrylic
 - B. Acetate
 - C. Terylene
 - D. Nylon
6. **Which fiber has high resistance to stains and mildew?**
 - A. Nylon
 - B. Acrylic
 - C. Acetate
 - D. Polyester
7. **Which fiber can melt or deform when exposed to heat?**
 - A. Terylene (Polyester)

- B. Acrylic
 - C. Acetate
 - D. Nylon
8. **Which fiber is most suitable for sportswear that needs quick-drying properties?**
- A. Acrylic
 - B. Polyester
 - C. Nylon
 - D. Acetate

Short-Answer Questions

1. How do the dyeing properties of acetate fibers affect their use in fashion?
2. Why is nylon an excellent choice for threads, bags, and shoes?
3. What makes acrylic fibers a popular wool substitute in winter clothing?
4. Explain how the thermal properties of polyester affect wearer comfort in summer clothing.

Chapter Seven: Advanced Industrial Fibres

7-1-Glass Fibres

Glass fiber also called fiberglass. It is material made from extremely fine fibers of glass. Fiberglass is a light weight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. Glass is the oldest, and most familiar, performance fiber. Fibers have been manufactured from glass since the 1930s.

7-1-1-Types of Glass Fiber

1. **A-glass:** With regard to its composition, it is close to window glass. In the Federal Republic of Germany, it is mainly used in the manufacture of process equipment.
2. **C-glass:** This kind of glass shows better resistance to chemical impact.
3. **E-glass:** This kind of glass combines the characteristics of C-glass with very good insulation to electricity.
4. **AE-glass:** Alkali resistant glass.

Generally, glass consists of quartz sand, soda, sodium sulphate, potash, feldspar and a number of refining and dyeing additives.

7-1-2-Properties of Glass Fiber

- Glass fibers are useful because of their high ratio of surface area to weight.
 - More susceptible to chemical attack.
 - By trapping air within them, blocks of glass fiber make good thermal insulation.
 - The freshest, thinnest fibers are the strongest because the thinner fibers are more ductile.
 - Because glass has an amorphous structure, its properties are the same along the fiber and across the fiber.
 - In contrast to carbon fiber, glass can undergo more elongation before it breaks.
 - The viscosity of the molten glass is very important for manufacturing success.
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Method	Description	Applications
Continuous filament process	Drawing long, continuous fibers from bushings	Reinforcements in composites
Staple fiber process	Produces short, discontinuous fibers by blowing molten glass with air/steam	Insulation materials
Centrifugal (Marble) process	Molten glass marbles spun into fibers by centrifugation	Wool-like glass insulation

1. Nozzle Drawing Process

Principle:

Molten glass flows through fine **nozzles (bushings)** and is **mechanically drawn (pulled)** into thin continuous filaments.

Steps:

1. Molten glass is held in a **platinum-rhodium bushing** at the bottom of the melting furnace.
2. It passes through **tiny holes (nozzles)** under gravity.
3. The glass threads are **pulled (drawn)** downward by high-speed mechanical winders.

4. The drawn fibers cool rapidly and solidify into **continuous filaments**.
5. A **sizing agent** is applied, and the fibers are wound onto spools.

Characteristics:

- Produces **continuous, uniform fibers** (diameter: 5–25 μm).
 - Used mainly for **reinforcement in composites** (e.g., fiberglass).
 - Offers **excellent control** over fiber diameter and quality.
-

2. Nozzle Blowing Process

Principle:

Molten glass is extruded through small nozzles and then **blown by high-pressure air or steam** into fine, short fibers.

Steps:

1. Molten glass is forced through multiple nozzles.
2. A strong **air or steam jet** strikes the emerging glass streams.
3. The air rapidly **stretches and cools** the molten glass into thin fibers.
4. The resulting fibers are **discontinuous** and collected on a moving screen or drum.

Characteristics:

- Produces **short, irregular fibers** (staple fibers).
 - Commonly used for **thermal and acoustic insulation (glass wool)**.
 - Less control over diameter compared to nozzle drawing.
 - **High production rate**, but fibers are not continuous.
-

3. Rod Drawing Process

Principle:

In this method, glass rods are used instead of molten glass. The rods are **heated and drawn** into fibers manually or mechanically.

Steps:

1. A solid **glass rod** is heated in a furnace until its end becomes soft.

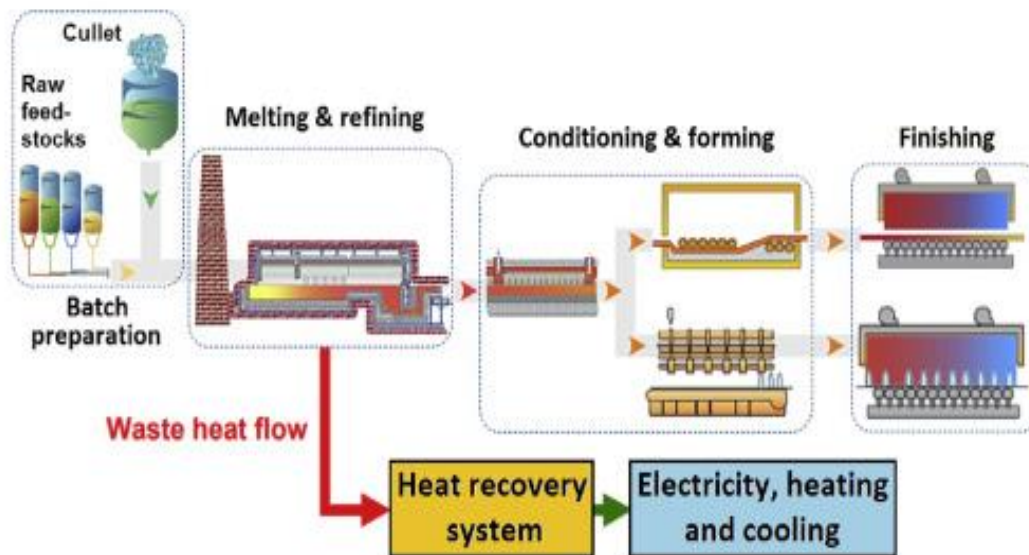
- The molten tip is **pulled (drawn)** to form a fine filament.
- The process can be **manual or automated** for small-scale fiber production.

Characteristics:

- Used for **experimental, laboratory, or small-scale** fiber making.
- Produces **short or continuous fibers**, depending on control.
- Fiber uniformity is **lower** than nozzle drawing.
- Useful for studying fiber properties or making optical fibers in early stages.

Comparison Summary

Feature	Nozzle Drawing	Nozzle Blowing	Rod Drawing
Raw Material	Molten glass	Molten glass	Glass rod
Fiber Type	Continuous	Discontinuous	Continuous or short
Method	Pulled through nozzles	Blown by air/steam	Drawn from heated rod
Control of Diameter	Excellent	Poor–moderate	Moderate
Application	Reinforcement fibers (composites)	Insulation (glass wool)	Lab-scale, optical fibers
Production Rate	High	Very high	Low



manufacturing process of glass melt

Uses of Glass Fibers / Glass Yarn

1. Construction and Civil Engineering

- **Reinforced Concrete (GRC):**
Glass fibers are mixed with cement to form *glass fiber reinforced concrete* panels, which are lightweight, corrosion-resistant, and durable.
- **Roofing and Wall Panels:**
Used in architectural cladding, ceilings, and insulation.
- **Pipes and Tanks:**
Glass-fiber reinforced plastics (GRP) are used for chemical storage tanks and pipelines.

2. Mechanical and Industrial Applications

- **Reinforcement in Composites:**
Combined with resins (epoxy, polyester) to produce strong, lightweight composite materials used in automotive and aerospace industries.
- **Machine Components:**
Used in fan blades, ducts, and casings where high strength and low weight are needed.
- **Mold Making:**
Glass fiber mats and fabrics are used in making molds for boats, vehicles, and industrial parts.

3. Automotive and Aerospace

- **Body Panels and Structures:**
Used to make hoods, bumpers, and body shells of cars and aircraft.
- **Interior Components:**
Used in dashboards, panels, and seat frames for rigidity and heat resistance.
- **Aircraft Parts:**
High-performance composites with glass fiber reinforcement are used for light but strong structures.

4. Electrical and Electronic Applications

- **Electrical Insulation:**
Glass fibers are excellent insulators — used in circuit boards, transformers, and cables.
- **Printed Circuit Boards (PCBs):**
Glass cloth impregnated with epoxy resin (FR-4) provides dimensional stability and insulation.
- **Electrical Tapes and Sleeves:**
Made from glass yarns to withstand high temperatures.

5. Textiles and Household Applications

- **Fireproof Fabrics:**
Glass yarn is woven into fabrics for **heat-resistant gloves, curtains, and protective clothing.**
- **Filter Fabrics:**
Used in filtration systems for hot gases and liquids.
- **Decorative Fabrics:**
For curtains, wall coverings, and screens due to their strength and non-flammability.

6. Scientific and Optical Uses

- **Optical Fibers:**
Special types of glass fibers transmit light for telecommunications and sensors.
- **Laboratory Equipment:**
Used in high-temperature filters, insulation, and support structures.

7. Thermal and Acoustic Insulation

- **Glass Wool (Fiberglass Wool):**
Made from short glass fibers; used for heat and sound insulation in buildings, refrigerators, and industrial equipment.

Carbon Fiber

Carbon fiber is a **synthetic fiber composed of carbon atoms** bonded together in a **crystalline structure.**

It's known for being **extremely strong, lightweight, and heat resistant.**



Structure of carbon fiber

Production:

1. **Precursor materials** (mainly *polyacrylonitrile* – *PAN*, or pitch) are spun into fibers.
2. Fibers are **oxidized and carbonized** at 1000–3000°C in an inert atmosphere.
3. The result is a **highly oriented carbon structure** with excellent mechanical properties.

Key Properties

Property	Description
Strength	Very high tensile strength
Weight	About 1/4 that of steel
Stiffness	High modulus of elasticity
Thermal Resistance	Excellent (stable up to 3000°C in inert atmosphere)
Corrosion Resistance	Excellent
Electrical Conductivity	Good (unlike glass fiber)

Applications of Carbon Fibers in Composites and Textiles

1. In Composite Materials

Carbon fibers are widely used as reinforcement in **polymer matrix composites (PMCs)**, **metal matrix composites (MMCs)**, and **ceramic matrix composites**

(CMCs) due to their **high strength-to-weight ratio, stiffness, and thermal stability**.

Main applications:

- **Aerospace:** Aircraft fuselage, wings, and turbine blades
- **Automotive:** Lightweight structural panels, racing car components
- **Civil Engineering:** Strengthening of concrete and bridges (carbon fiber-reinforced polymers – CFRP strips)
- **Sports Equipment:** Tennis rackets, bicycles, fishing rods

Carbon fibers in composites enhance **mechanical strength, fatigue resistance, and dimensional stability** while reducing overall weight.

2. In Textiles

Carbon fiber fabrics and yarns are used in **technical textiles** for high-performance and protective applications.

Examples:

- **Protective clothing:** Fire-resistant suits and gloves
- **EMI shielding fabrics:** To protect electronic devices from electromagnetic interference
- **Reinforcement fabrics:** In composite laminates and aerospace textiles
- **Smart textiles:** Integrated with sensors and heating elements

These fabrics combine **lightness, durability, and conductivity**, making them ideal for multifunctional textiles.

3. Microelectrodes

Carbon fibers are used to fabricate **microelectrodes** for biomedical and electrochemical applications because of their **excellent electrical conductivity, chemical stability, and biocompatibility**.

Applications include:

- **Neural recording and stimulation** (detecting brain activity)
- **Electrochemical sensors** (for detecting dopamine, glucose, etc.)
- **Microelectromechanical systems (MEMS)**

- **Energy devices** (micro-batteries and supercapacitors)

Advantages:

- High surface area
- Fast electron transfer
- Mechanical flexibility
- Minimal biological interference

4. Flexible Heating Elements

Carbon fiber-based fabrics and films act as **flexible heating materials** due to their **electrical conductivity and thermal stability**.

Applications:

- **Wearable heaters** (jackets, gloves, medical wraps)
- **De-icing systems** for aircraft or vehicles
- **Floor and seat heating**
- **Smart textiles** integrated with temperature control

Working principle:

When an electric current passes through carbon fibers, **Joule heating** occurs — the fibers convert electrical energy into uniform heat over a flexible surface.

Comparison: Glass Fiber vs Carbon Fiber

Property	Glass Fiber	Carbon Fiber
Density	Higher (heavier)	Lower (lighter)
Tensile Strength	High	Very high
Elastic Modulus	Moderate	Very high
Electrical Conductivity	Insulator	Conductor
Cost	Low	High
Thermal Resistance	Good	Excellent
Impact Resistance	Good	Moderate (brittle)
Applications	General, construction	Aerospace, high-performance

Aramid Fibers (Aromatic Polyamides)

Definition

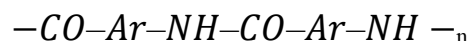
Aramid fibers are a class of **synthetic fibers** derived from **aromatic polyamides**. They are known for their **exceptional strength, heat resistance, and toughness**, making them suitable for high-performance and protective applications.

The most well-known commercial aramid fibers are **Kevlar®** and **Nomex®**, both developed by DuPont.

Chemical Structure

- Aramid = *Aromatic + Polyamide*
- The polymer chains consist of **aromatic rings** and **amide linkages (-CO-NH-)**.
- These strong covalent bonds and high molecular orientation provide **high tensile strength and thermal stability**.

General chemical formula:



(where **Ar** represents an aromatic ring)

Types of Aramid Fibers

Type	Example	Main Properties	Applications
Para-aramid	Kevlar®	Very high strength and modulus	Bulletproof vests, ropes, composites
Meta-aramid	Nomex®	Excellent thermal and flame resistance	Firefighter suits, insulation, protective clothing

Manufacturing Process

1. **Polymerization** – Production of aromatic polyamide polymer from monomers such as *p-phenylenediamine* and *terephthaloyl chloride*.
2. **Spinning** – The polymer is dissolved in a solvent and extruded through spinnerets into a **coagulation bath** (wet spinning process).
3. **Drawing/Stretching** – Fibers are stretched to align the molecular chains for higher strength.
4. **Winding and Finishing** – Fibers are wound into yarns or fabrics for industrial or textile use.

Key Properties

Property	Description
Tensile Strength	Very high (5–6 times stronger than steel by weight)
Thermal Resistance	Stable up to 400°C; does not melt
Flame Resistance	Self-extinguishing; excellent for fire protection
Chemical Resistance	Resistant to most organic solvents and fuels
Elastic Modulus	High stiffness
Electrical Conductivity	Non-conductive (insulator)
Density	Low (~1.44 g/cm ³) – lightweight

Applications

1. Protective Equipment

- **Bulletproof vests, helmets, and gloves** (Kevlar)
- **Firefighter suits and heat-resistant apparel** (Nomex)
- **Cut-resistant and ballistic armor**

2. Composites

- **Aerospace and automotive structures**
- **Boat hulls, aircraft panels, and sporting goods**
- Often combined with **carbon or glass fibers** to improve toughness and impact resistance.

3. Industrial Uses

- **Belts, ropes, and cables** (high tensile strength and fatigue resistance)
- **Reinforcement in rubber products** (e.g., tires, hoses)
- **Electrical insulation and honeycomb structures**

4. Other Applications

- **Aerospace thermal shielding**
- **Filtration fabrics** in high-temperature environments
- **3D-printed composites** with aramid reinforcement

Comparison: Aramid vs Carbon vs Glass Fibers

Property	Aramid Fiber	Carbon Fiber	Glass Fiber
Density	Low	Moderate	High
Tensile Strength	Very high	Very high	High
Stiffness (Modulus)	Medium–high	Very high	Medium
Impact Resistance	Excellent	Moderate	Good
Thermal Resistance	Excellent	Excellent	Good
Electrical Conductivity	Insulator	Conductor	Insulator
Cost	Medium–High	High	Low
Typical Use	Armor, heat protection	Aerospace, automotive	Construction, insulation

A. TRUE or FALSE Questions

1. Glass fibers are organic fibers made from petroleum-based polymers. → **False**
2. Carbon fibers have higher stiffness and strength than glass fibers. → **True**
3. Aramid fibers melt easily when exposed to high heat. → **False**
4. Glass fibers are good electrical conductors. → **False**
5. Carbon fibers are electrically conductive and thermally stable. → **True**
6. Aramid fibers are resistant to flames and do not melt. → **True**
7. Glass fibers are commonly used in insulation materials. → **True**
8. Carbon fibers are heavier than steel. → **False**
9. Aramid fibers are known for their high impact and cut resistance. → **True**
10. All three fibers are used as reinforcement in composite materials. → **True**

B. Multiple-Choice Questions

1. The main chemical component of glass fibers is:

- a) Polyacrylonitrile
- b) Cellulose
- c) Silica (SiO₂)
- d) Carbon black

→ **Answer: c) Silica (SiO₂)**

2. Which of the following fibers has the highest tensile strength-to-weight ratio?

- a) Glass fiber

- b) Carbon fiber
- c) Aramid fiber
- d) Nylon fiber

→ **Answer: b) Carbon fiber**

3. Aramid fibers such as Kevlar and Nomex are types of:

- a) Polyesters
- b) Aromatic polyamides
- c) Polyethylene
- d) Polypropylene

→ **Answer: b) Aromatic polyamides**

4. Glass fibers are mainly produced using which process?

- a) Wet spinning
- b) Melt spinning through bushings
- c) Electrospinning
- d) Gel spinning

→ **Answer: b) Melt spinning through bushings**

5. Which fiber is most suitable for electrical insulation?

- a) Carbon fiber
- b) Aramid fiber
- c) Glass fiber
- d) Steel fiber

→ **Answer: c) Glass fiber**

6. The main disadvantage of carbon fibers is:

- a) High density
- b) Low tensile strength
- c) High cost and brittleness
- d) Low stiffness

→ **Answer: c) High cost and brittleness**

7. Aramid fibers are widely used in:

- a) Bulletproof vests and fireproof suits
- b) Car tires only
- c) Food packaging
- d) Plastic toys

→ **Answer: a) Bulletproof vests and fireproof suits**

8. Which of the following is an electrical conductor?

- a) Glass fiber
- b) Aramid fiber
- c) Carbon fiber
- d) All of them

→ Answer: c) Carbon fiber

9. The fiber most commonly used for thermal and acoustic insulation is:

- a) Carbon fiber
- b) Glass fiber
- c) Aramid fiber
- d) Nylon fiber

→ Answer: b) Glass fiber

10. Aramid fibers can resist temperatures up to about:

- a) 100°C
- b) 200°C
- c) 400°C
- d) 600°C

→ Answer: c) 400°C

C. Explanations and Key Concepts

1. Glass Fibers

- Made from **molten silica** and other oxides.
- **Properties:** High tensile strength, corrosion resistance, low cost, non-conductive.
- **Uses:** Building insulation, reinforced plastics, boat hulls, and automotive panels.

2. Carbon Fibers

- Made by **carbonizing** precursor materials like *polyacrylonitrile (PAN)*.
- **Properties:** Very high strength and stiffness, light weight, electrically conductive, thermally stable.
- **Uses:** Aerospace parts, sports equipment, racing cars, and high-end composites.

3. Aramid Fibers

- Synthetic **aromatic polyamides** such as *Kevlar* and *Nomex*.
- **Properties:** High tensile strength, flame resistance, excellent impact resistance, low density.
- **Uses:** Bulletproof vests, firefighter suits, ropes, and composite reinforcements.