PAPER: SCIENCE AND SUSTAINABILITY

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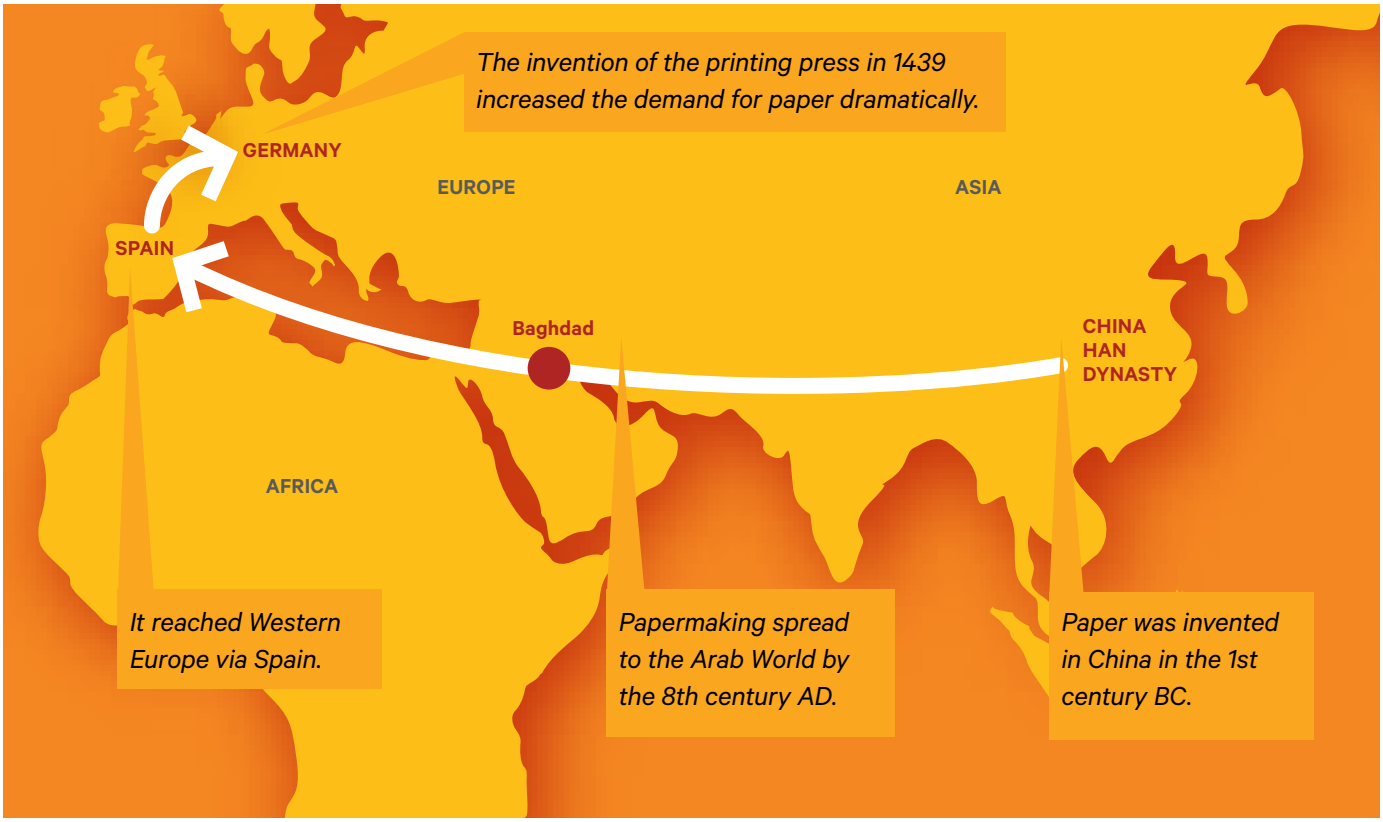
INTERNATIONAL PAPER

HAMMERMILL®

Part I

Introduction to PAPER SCIENCE



PAPER WAS INVENTED IN CHINA AROUND 140 BC

For centuries, the Chinese jealously guarded the art of papermaking as a trade secret. However, by the 8th century AD, the Arab world had acquired it. In fact, a paper mill was established in Baghdad as early as 794 AD.

Paper: a Modern Product with Ancient Roots

While paper is an ancient medium, it wasn't the first surface on which humans recorded their thoughts and ideas. Before paper was invented, people wrote on a range of materials, including dried animal skins and bones, sea shells, silk, papyrus, and stones. In fact, Homer's *The Iliad* and the *Epic of Gilgamesh* were recorded on clay tablets. If you think your book bag is heavy now, just imagine if every page in your textbook was replaced with a clay tablet. The limitations of these writing media are obvious: clay tablets are extremely heavy, shells are prone to break, and writing on silk can wash away.

WE USE PAPER EVERY DAY

The first written record that mentions paper is dated AD 105.

We print out our reports on it. We jot things down in notebooks. Our most important documents, from our passport to our birth certificate to our high school diploma, are printed on paper. It can be difficult to imagine a time when people did not use paper. From the start, this new medium had clear advantages over other writing surfaces. It was cheap to produce. Its light weight made it highly portable and surprisingly durable. And, writing on paper had a special quality that made it valuable for government business. Whereas writing on clay or stone could be scraped off and re-inscribed, ink on paper penetrates the page. That made it a reliable medium for official documents and messages that needed to be conveyed across long distances.

The first written record that mentions paper is dated AD 105, when Ts'ai Lun, a eunuch in the imperial court of the emperor Ho Ti announced the invention of paper in a formal report and outlined how it was made. However, archaeologists discovered paper fragments in China dating back to the first century BC, which proves paper existed much earlier than AD 105.

China's Trade Secret Gets Out

From the start, papermaking was a model of recycling. In ancient China, the base material for papermaking was primarily old rags, such as used fishnets, in addition to hemp, mulberry bark and other materials. When torn-up rags were cooked at high temperature, they would decompose into a pulp which, after being pressed and dried, would become paper.

As the process for making paper was shared across the Arab world, it spread across the Middle East, North Africa and Spain from where it reached Western Europe. By the Middle Ages, reading books was a central part of religious and scholarly life in Europe. Throughout this period, books were copied out one by one, by hand. This made books extremely valuable and costly. It also made them rare. Private ownership of books was limited to the extremely wealthy.

JOHANNES GUTENBERG

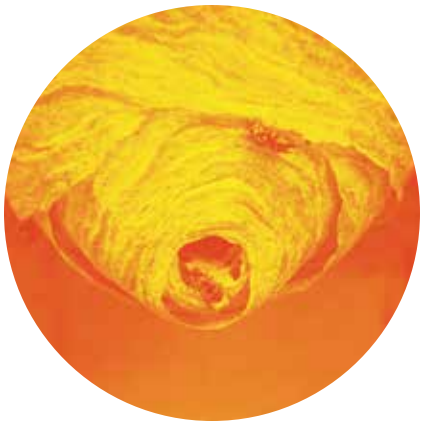
Printing presses blossomed across Europe, and the demand for paper grew exponentially.

That began to change in 1439, when a German blacksmith named Johannes Gutenberg invented a mechanical method of producing books. Called the printing press, Gutenberg's invention used movable type to enable the mass production of books. Suddenly, books could be produced much more quickly and cheaply. Printing presses blossomed across Europe, and the demand for paper grew exponentially.

From Rags to Wood

As the demand for paper grew, a significant challenge emerged. Well into the Industrial Revolution, people were still using old rags as the raw material for pulp. This was not only unhygienic, it was impractical. As more and more paper was needed, the demand for rags and other detritus exhausted the supply. By the 1700s, American paper mills were looking for an alternative to rags for paper production. Thanks to a French scientist, they found it in wood.

WASPS & RENÉ RÉAUMUR



Paper Wasp nest

In 1719, on a visit to America, René Antoine Ferchault de Réaumur observed that certain wasps made a nest of paper after chewing and digesting bits of wood. These paper nests gave him an idea for solving the shortage of rags needed for papermaking. The wasps, the Frenchman wrote, "seem to invite us to try whether we cannot make fine and good paper from the use of certain woods."

At the time, North America, unlike Europe, was covered in forests. But which woods would be best for making paper? The answer lay in **cellulose fiber.** All plants and trees have cellulose fiber, but some trees have greater cellulose fiber density than others. Trees with a very high yield of cellulose fiber are best for papermaking. However, there are other considerations, too. The fiber from one tree might be good for making very strong paper, while the fiber from another tree might be good for making very smooth paper.

Today, we can see the fiber density of certain trees under a microscope. In the 1700s, trial and error proved which trees were ideal for papermaking. Depending on the type of paper needed, pulp made from short-wood and long-wood trees may be mixed to produce the desired degree of texture and strength.[1]

The following page shows the differences between fibers from softwood and hardwood trees, as well as some of the tree species that are often used in paper production.

[1] René-Antoine Ferchault Réamur, *A History of wasps* (1719).

Naturally Different Tree Fibers

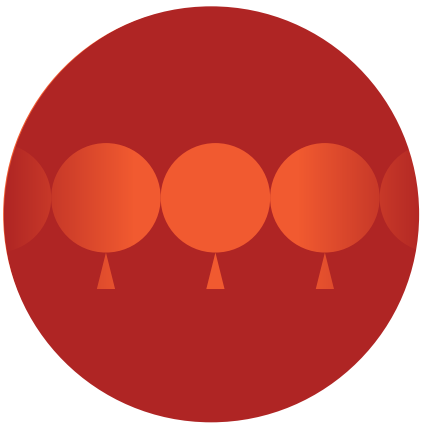
Needleleaf or Evergreens

SOFTWOOD

Tree Types	Pines, Hemlocks and Firs
Cellulose Fiber Percentage	90–95%
Type of Fiber	Long Fibers 3-7 mm in length A Norway Spruce will have a fiber wall of 2–5 mm
Uses	Strength, foldability and packaging

HARDWOOD

Tree Types:	Aspens. Beeches, Gums, Maples, Mountain–Ash, Cedar, Ironbark, Stingybark and Oaks
Cellulose Fiber Percentage:	27–76%
Type of Fiber:	Short Fibers 1–2mm in length (2/3 as thick as softwoods), very strong A ***pinus radiata*** might have twice the fiber wall thickness of a Norway Spruce.
Uses:	Strength, foldability and packaging



Broadleaved Trees

What is so Special about Cellulose Fibers?

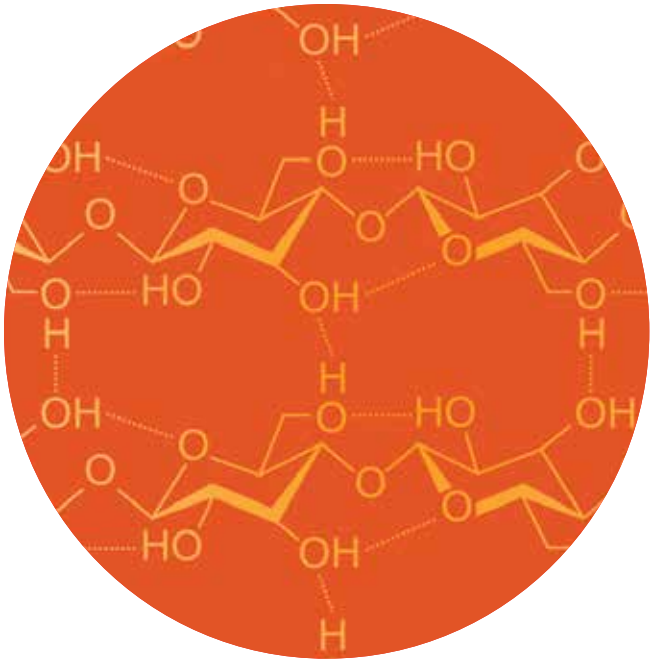
Softwood fibers

Hardwood fibers

If you've ever made paper at home, you may have experienced a sense of wonder as the messy slurry[2] created from pulp dries to form a perfectly smooth sheet of paper. How does this effect happen with little more than a screen and the time for the pulp to dry?

The answer is hydrogen bonding. Hydrogen bonding allows cellulose fibers to bind to one another as tightly as if they had a magnetic attraction. In fact, some people describe paper as a "hydrogen-bonded solid."

Within each cellulose fiber are fibrils, and within each fibril are microfibrils. Holding it all together like glue is lignin and hemicellulose. However, these substances are not needed for pulp. In order to access the cellulose fibers in wood for paper production, the cellulose has to be separated from the lignin and the hemicellulose. This is done through a process called pulping.



Hydrogen bonding

Hydrogen bonding allows cellulose fibers to bind to one another as tightly as if they had a magnetic attraction. In fact, some people describe paper as a "hydrogen-bonded solid."

[2] Slurry is the loose mixture of water and pulp used to form paper.

Sustainable Forestry

Taking an active approach to responsible forest stewardship creates value for landowners, communities, customers, and ecosystems on a global scale. A continuous cycle of planting, cultivation and harvesting ensures that working forests remain robust and healthy.

"A significant challenge for the forestry profession is to communicate that one of the best ways to save a forest is to use it."
— Food and Agriculture Organization of the United Nations State of the World Forests Report 2012

Forests cover more than 30% of the earth's surface—almost 10 billion acres.[3] Almost two-thirds are considered working forests, land that is actively managed to generate multiple resources, including wood fiber, recreation, wildlife, aesthetics, clean water and other forest ecosystem values. When managed responsibly, working forests can produce a continuous and sustainable supply of these resources. Less than 1% of the wood from these forests is harvested each year. The remaining one-third of the global forested area is considered primary forest, where human activities have been limited or are entirely absent.

Around the world there are many concerns about the impact of deforestation on the global environment. Deforestation increases carbon dioxide emissions to the Earth's atmosphere. The highest rates of deforestation occur in tropical countries and are driven by forestland conversion to agriculture, fuel production and development. Although this trend is beginning to slow, and even reverse in some cases, it remains a concern for many scientists.

[3] Calculated on the basis of 2015 total land area. Source: *Global Forest Resources Assessment 2015, How are the world's forests changing? Second edition.* Food and Agriculture Organization of the United Nations, Rome 2016.

Primary Forests and Working Forests

33%

Primary forests make up approximately 33% of the earth's forests. These forests regenerate through natural processes and are not managed for harvesting purposes.

66%

Working forests consist of natural, semi-natural, and plantation forests that cover about 66% of the earth's forests. These forests regenerate naturally and by replanting trees. 90% of forestland in the U.S. is owned by private forestland owners.

Because of its high cellulose content, wood is essential to paper production. Counter-intuitively, the demand for wood for paper products has not only protected working forests, but contributed to an increase in forest cover in the developed world. Today, there are 25% more trees in the developed world than there were in 1901.

In order to grasp the environmental impact of papermaking, it is helpful to recognize that there are different types of forests: working forests and primary forests are two examples.

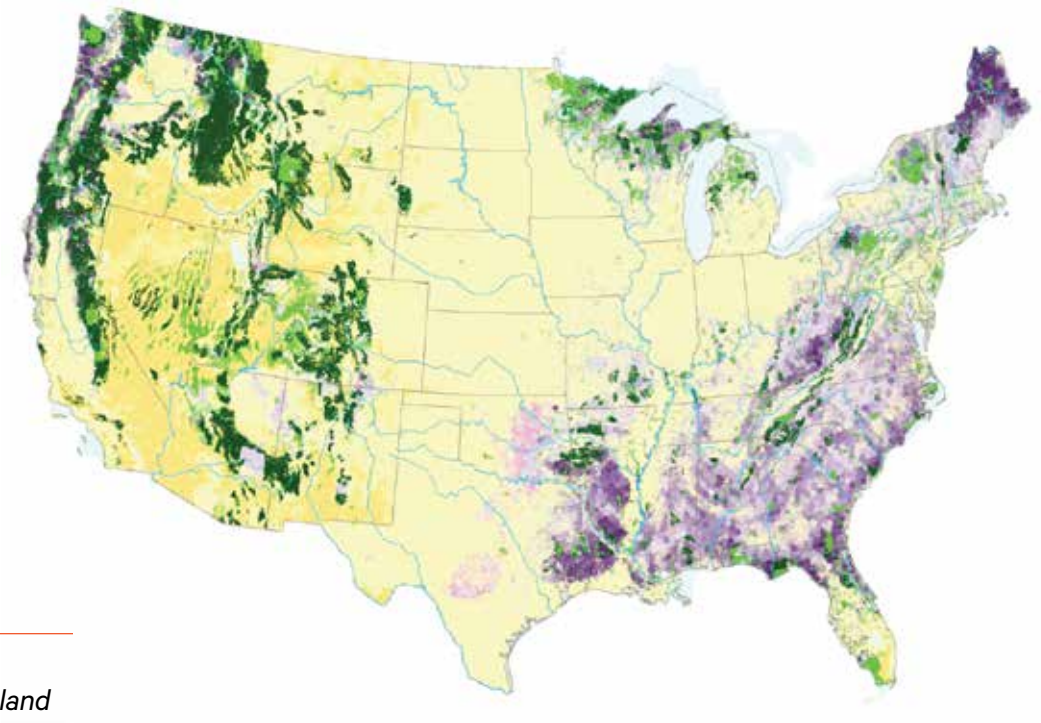
Primary Forests are forests where trees have grown naturally for thousands of years with little human intervention. The South American rain forest is a primary forest, as is the Tahoe National Forest in California. Many of these lands are protected by national and international laws from illegal logging and harvesting. About a third of all forests on the earth's land surface are primary forests.

PRIMARY FORESTS & WORKING FORESTS

In contrast, working forests are managed to yield a harvest—in this case wood. Working forests are very carefully tended to ensure their long-term health. Less than 1% of the trees in a working forest are harvested each year. And for every one tree that is harvested, three more are planted. This protects the overall vitality of the forest and the ecosystem it supports. About two-thirds of all forests on earth's land surface are working forests.

United States

FOREST OWNERSHIP



Forest Ownership in the Contiguous United States*

- *Private Forest, 100% Corporate*
- *Private Forest, 0% Corporate*
- *National Forest*
- *Other Public Forest*
- *Public Land, not Forest*
- *Private Land, not Forest*
- *No Data*

Spatial distribution of forest land across the conterminous United States, differentiated into public vs. private forest land. Over two-thirds of western forest land is publicly owned. In the East, more than 80 percent of forest land is privately owned.

* Figure source: U.S. Forest Service 2012, *Future of America's forest and rangelands: 2010 Resources Planning Act Assessment.* General Technical Report WO-87 (2545714a)

Who Owns the Forests?

The map on the opposite page shows something that may surprise you: most woodlands in the United States are privately owned. And most of the owners of privately owned woodlands are not corporations or nonprofits, but individual families. In many cases, these "tree farmers" have managed their working forests for generations. By sustainably managing their forests, they can earn money from their land while making sure that their forests can be passed down to the next generation.

TREE FARMERS

Members of the Vinson Family from Hamilton, Alabama.

With so many private owners of woodlands farming trees, it is important to make sure that all tree farmers are practicing responsible forest management. That means using techniques that are friendly to the environment and to the animals that live in forests.

The Vinson family from Alabama have been tree farmers for over 60 years. In 1956, the family patriarch, Nelson Vinson, first started farming trees. He bought 127 acres and planted 1,000 trees per acre. More than a half century later, he can point out the trees he planted from the ones that sprouted naturally—a remarkable ability, especially given the size of his property. His wife, Terry, shares his passion for land.

Like many private owners of woodlands, Nelson had opportunities to sell his land so that it could be cleared for development as a residential estate. Fortunately, he didn't need to. His family's land is able to generate an income from the crop it grows: trees. In fact, the Vinsons earned more money from tree farming than from Nelson's successful law practice. That is why he raised his kids to "go hungry, but never sell your land." Nelson knows that when you take care of the land, the land will take care of you.

Third party certification of sustainable forest management practices is one way to verify forest stewardship.

FSC: Forest Stewardship Council, us.fsc.org/en-us; PEFC: Programme for the Endorsement of Forest Certification, pefc.org; SFI: The Sustainable Forestry Initiative, sfiprogram.org

FSC
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SFI-00006

United States Biomass

NASA Earth Observatory Map of Biomass in the United States

Take a look at the map produced by NASA that shows biomass[4] in the United States. You might observe that forests in our country are mostly concentrated in the Northeast and South, as well as in the Northwest. Now look at the second map on the next page, which shows the locations of pulp and paper mills and associated offices. Do you notice a connection between the two?

If you superimposed one map on top of the other, you would find that pulp and paper mills are located in or near forests. And that makes a good deal of sense. The sites of paper production have historically been located close to the sources of its raw material: wood.

[4] Biomass means organic matter from living organisms, usually plants.

Where are the Pulp & Paper Mills?

Can you identify which are paper and which are paperboard mills?

Paper and Paperboard Mills of International Paper in the Contiguous United States

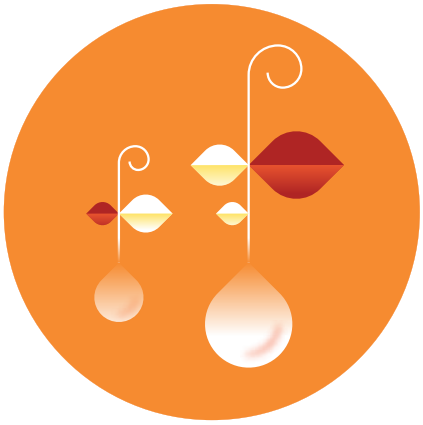
- *Global Headquarters*
- *Consumer Packaging*
- *Global Cellulose Fibers (GCF)*
- *Industrial Packaging (IPG)*
- *North American Papers (NAP)*
- *Shared Mill (GCF/NAC)*
- *Shared Mill (GCF/NAP)*

For that reason, most pulp and paper mills are located in the South, the Northeast and the Northwest. In contrast, mills that recycle paper are typically located near cities because cities are a major source of used paper.

It is worth noting, however that not all paper production sites are located in or near working forests. Some mills carry out only one part of the papermaking process. For example, one mill may only convert logs into wood chips. Another mill may only convert wood chips into pulp. And another mill may only convert pulp into paper. In these cases, both the raw material and the end product may have to be shipped, often across oceans, to the next mill in the process.

Comprehension

Based on your reading of pages 8-13, answer the following questions:



1. *The author provides the information regarding the ancient Chinese invention of paper in order to:*

- ◯ **a.** Introduce the central idea of the many significant inventions that originated in Ancient China.
- ◯ **b.** Compare the process of paper production between ancient China and today.
- ◯ **c.** Provide historical context for the subject of paper production.
- ◯ **d.** Illustrate that paper is a part of the cultural heritage of the East.

2. *What reason would best explain China guarding the paper-making process as a trade secret?*

- ◯ **a.** They wanted to retain the revenue from controlling the supply of paper.
- ◯ **b.** They were concerned that if the art of papermaking spread beyond China, it would cite geopolitical unrest.
- ◯ **c.** They wanted to protect the quality of paper by controlling the number of people who knew how to make paper.
- ◯ **d.** They were concerned people from other parts of the world would make paper better than they could.

6. *The idea to rely on wood as the raw material for papermaking can best be described as:*

- ◯ **a.** A fortuitous observation of a scientist observing insects.
- ◯ **b.** A notion that was obvious to most paper producers.
- ◯ **c.** An example of how insects are the better engineers than humans.
- ◯ **d.** An idea that began in China with the earliest inventor of paper.

7. *From the passage, you can infer that both rags and wood are effective raw materials for paper production because:*

- ◯ **a.** They contain oxygen.
- ◯ **b.** They contain lignin.
- ◯ **c.** They contain cellulose.
- ◯ **d.** They contain hydrogen.

Questions

3. *The author describes a range of materials that people wrote on before the invention of paper in order to illustrate that:*

- ◯ **a.** Human beings are extremely resourceful.
- ◯ **b.** Found objects are not as good as manufactured ones.
- ◯ **c.** Human beings are, by definition, born writers.
- ◯ **d.** Writing predates paper.

4. *The author posits that paper was first invented in China in the first century BC, even though the earliest written record of paper is from the first century AD. What evidence does the author provide to support the earlier date?*

- ◯ **a.** DNA evidence of Emperor Ho Ti.
- ◯ **b.** Archaeological evidence of early paper fragments.
- ◯ **c.** Citations of historians considered the most respected in the field of Chinese history.
- ◯ **d.** Mathematical calculations.

5. *How did the invention of the printing press impact paper production?*

- ◯ **a.** It created a wider array of suppliers of paper across Europe.
- ◯ **b.** It made books much cheaper and more accessible.
- ◯ **c.** It created a massive demand for paper.
- ◯ **d.** It rendered the work of copyists obsolete.

8. *What is hydrogen bonding?*

- ◯ **a.** A highly electronegative atom that repels the force of another highly electronegative atom.
- ◯ **b.** The stable balance of attractive and repulsive forces between atoms when they share electrons.
- ◯ **c.** The force between the hydrogen attached to an electronegative atom of one molecule and an electronegative atom of a different molecule.
- ◯ **d.** A type of chemical bond that generates two oppositely charged ions to become a positively charged ion.

9. *Most privately owned woodlands are owned by:*

- ◯ **a.** Large corporations.
- ◯ **b.** The government.
- ◯ **c.** Nonprofit organizations.
- ◯ **d.** Individual families.

10. *More than half the nation's paper & pulp production takes place in the southern states. This can best be explained by:*

- ◯ **a.** The preponderance of forests in the southern states.
- ◯ **b.** The preponderance of family tree farmers in the southern states.
- ◯ **c.** Favorable economic factors that incentivize companies to locate in the southern states.
- ◯ **d.** Favorable climatic conditions that incentivize companies to locate in the southern states.

Comprehension

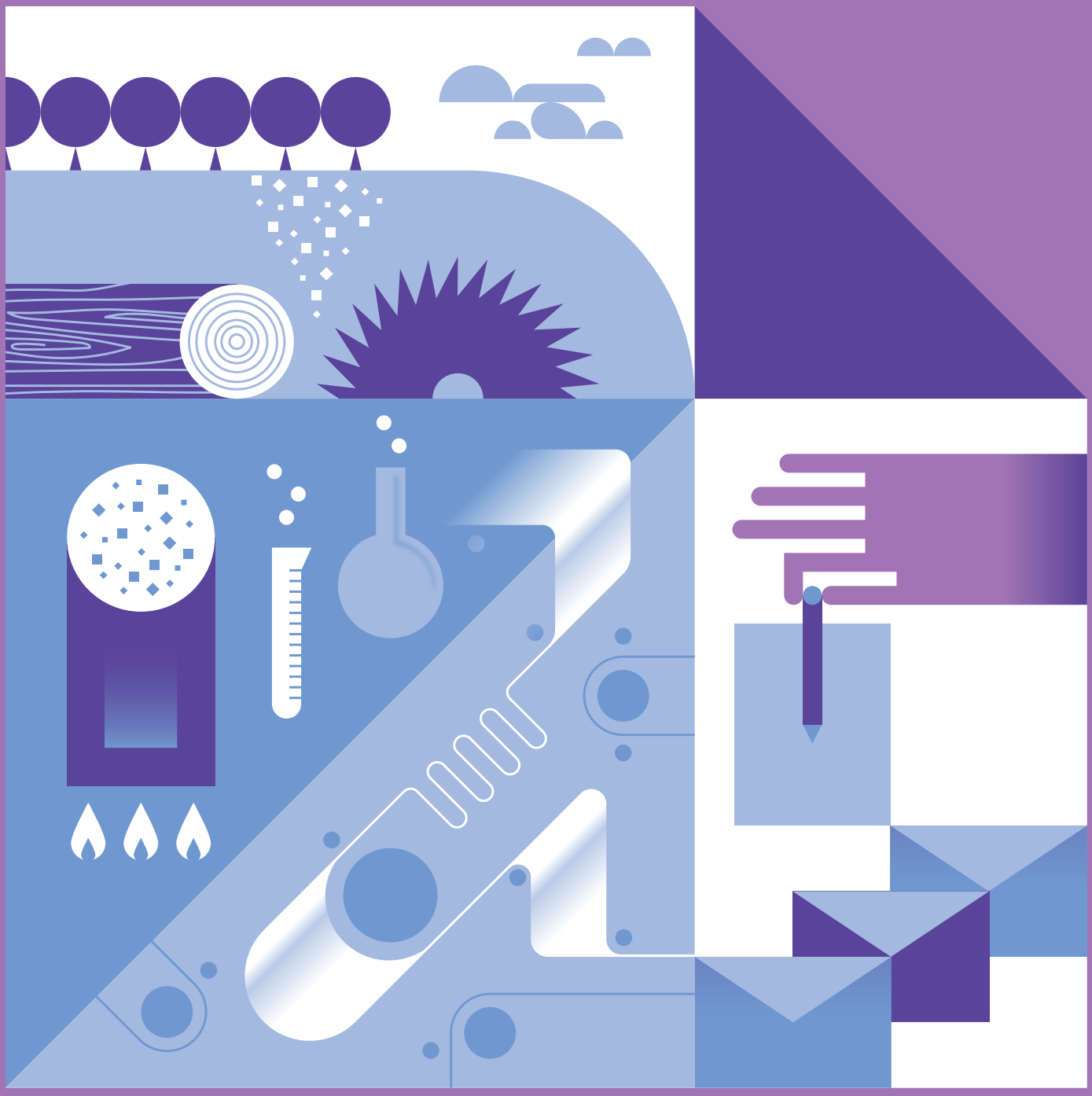
“When people use more paper, suppliers plant more trees. If we want bigger commercial forests, then we should use more paper, not less.”

—Edward L. Glaeser, Professor of Economics at Harvard University

Which concepts and information introduced in pages 8 through 13 support the claim presented in the quote above?

Your answer should be supported by a minimum of two citations.

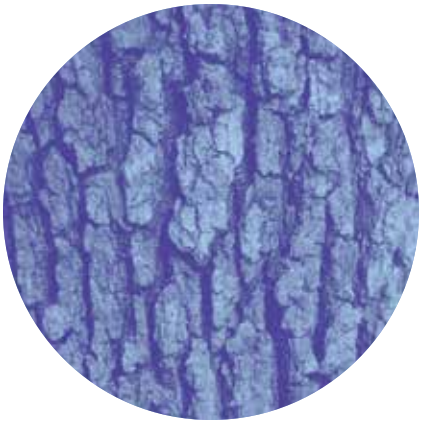
Short Response



Paper MANUFACTURING

21st Century Paper Production

The U.S. forest and paper industry employs 1.6 million Americans.



Tree bark

Tree bark is preserved for use in biofuel.

We've come a long way from the handmade papermaking practices of ancient China. Today, the pulp and paper industry is one of the largest industrial sectors in the world. The industry generates about $170 billion in annual revenues. The U.S. forest and paper industry employs 1.6 million Americans, or 1.2% of the U.S. workforce.

While today's papermaking processes are highly automated, the complex nature of the process demands skilled workers to monitor the processes with care. Three-quarters of the 500,000 jobs in the pulp and paper industry are in production and manufacturing. Many of these employees are engineers and highly trained professionals supervising large machinery producing pulp and paper on a massive scale.

NO PART OF THE TREE IS WASTED

To describe 21st century paper production, we have to begin in a working forest. When trees are harvested from a working forest, they are sawed into logs between four and eight feet in length. Then, they are brought to a **mill** site.

At the mill, operators feed the logs into a rotating cylinder drum, also known as a **de-barker**. As the logs move through the drum, the rotating action of the drum removes the bark off of the logs. The bark is preserved for use in **biofuel**[5] so that no part of the tree is wasted. Next, the logs are cleaned, so that dirt, dust and other impurities are washed away.

The valuable part of the wood for paper production is **cellulose**.[6] In order to isolate cellulose fibers, the other parts of the wood, such as lignin, must be separated in the pulping process.

[5] Biofuel is a fuel derived directly from living matter.

[6] Cellulose is an insoluble substance that is the main ingredient of plant cell walls.

The Pulping Process

Wood Chips

Before the **pulping** can begin, the logs need to be cut down to a manageable size. They are fed into a wood chipper, which shreds the logs into "chips" about one inch in length. Dividing the wood into one-inch chips makes it much easier to cook. All the wood chips are cut into the same size chip to ensure that every chip will dissolve in a set amount of time. This makes for optimum and consistent pulping.

The wood chips are metered into a machine called a **"digester."** A digester acts as a highly engineered pressure cooker in which wood chips are mixed with water and chemicals and subjected to high pressures and hot temperatures. Digester operators monitor their instruments to ensure that the cooking temperature and pressure is appropriate to dissolve the lignin[7] and break down the chips into pulp. It can take about eight hours for the digester to cook the chips until they turn into cooked cellulose fiber. During the hours in the digesters, the unwanted materials in the wood chips, such as lignin, are dissolved by the chemicals. The end result is **pulp**: the pure cellulose fiber that is the main ingredient of paper.

Digester

A digester acts as a highly engineered pressure cooker in which wood chips are mixed with water and chemicals and subjected to high pressures and hot temperatures.

[7] Lignin is an organic substance that, together with cellulose, forms most of the composition of wood. For papermaking, lignin needs to be separated from the cellulose to make high-quality pulp.

Cleaning & Bleaching

Bleached Pulp

Bleaching oxidizes the pulp into a bright white color.

The cooked pulp is always brown when it comes out of the digester. It is washed and filtered through a series of screens to filter out the chemicals that were used in the cooking process. Sometimes, a centrifugal cleaner uses gravity to separate out heavier contaminants from the clean pulp. This also has the effect of making the pulp.

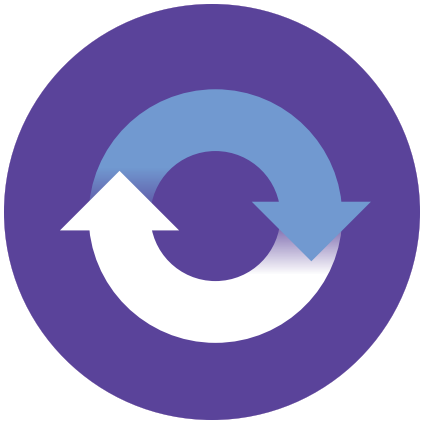
At this point, the pulp resembles the properties required to make brown paper bags. However, to produce paper that we can write on and use for printing, a few more steps are needed. The first is **bleaching**.

If you look at paper written on centuries ago, you may notice that it has yellowed with age and even become fragile over time. Now, with technological advancements, paper can last for centuries and retain the original color. Bleaching counteracts the natural color of fiber and gives it a bright white color. Bleach also has the effect of disintegrating any tiny parts of wood that are still in the pulp. This gives bleached paper a high level of purity and polish. While household bleach was used before the 1930s in industrial paper production, environmental concerns have discouraged its use. Today chlorine dioxide is mainly used in the bleaching process.

At this point, the pulp can also be **dyed** other colors, if papers of other tints are desired. In a huge tank, beater engineers blend dye, chemicals, and water with the pulp. Depending on how long they beat the contents together, they will produce paper of different strength, color hues and saturation.

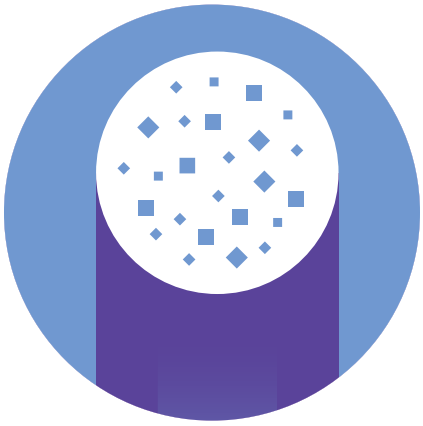
Papermaking on an industrial scale requires powerful machines and a wide array of chemical solutions. Engineers and operators observe strict safety precautions and processes to maintain a safe working environment. They also ensure that the machines are energy-efficient, using as little energy as possible.

Paper Recycling



Much of the paper we use today is recycled. Thanks to recycling programs, 63% of all paper and paperboard used in America is deposited for recycling and reuse. There are different types of recycled paper. White office paper is recovered and recycled to make premium recycled white office paper. For example, Hammermill® Great White® 30, 50 and 100 has recycled content.

Recovered paper is put into a large blender-like machine called a **pulper** that separates the fibers. While the used paper has now been turned into pulp, it is not yet ready to be turned into paper. This is because the ink that was on the used paper is now in the pulp. To get the ink and foreign materials like glue out of the pulp, it has to be separated from the cellulose fibers.



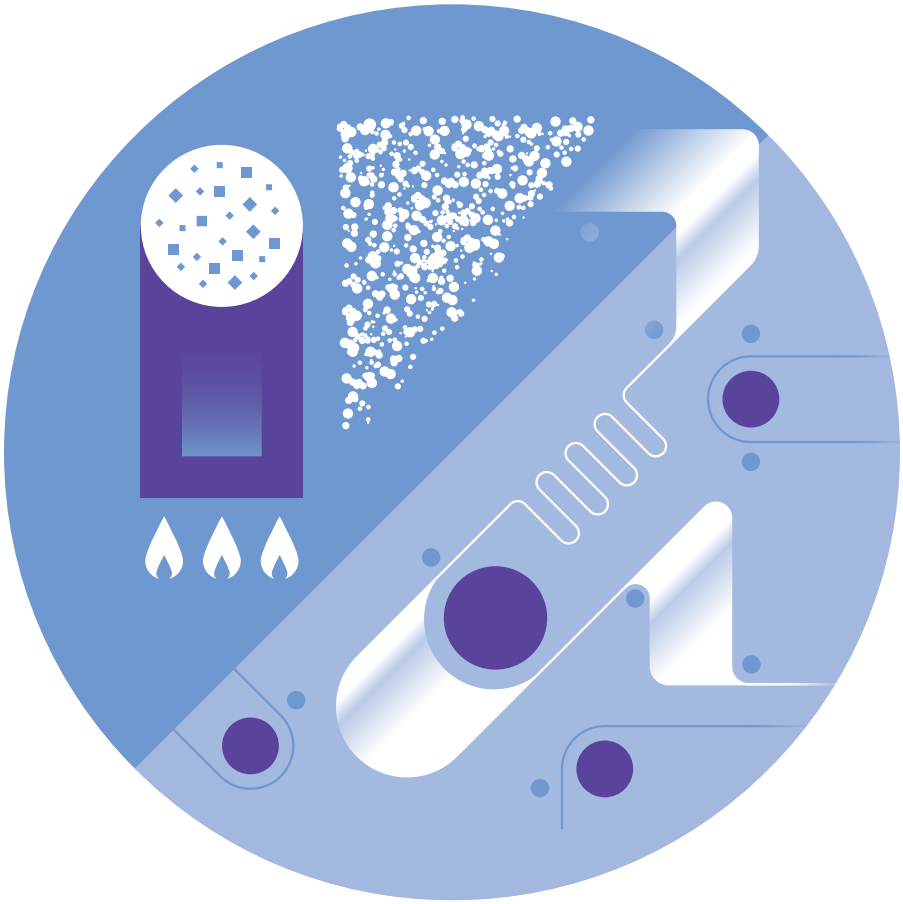
Froth Flotation

Engineers remove the ink and other impurities by pouring the pulp into a **froth flotation cell** which liberates them from the cellulose fibers. Bubbles are created in the froth flotation cell, which bond with the ink particles and other impurities. As the bubbles rise to the surface, they carry the ink and impurities with them. Then the bubbles are removed from the surface. Now, the cellulose fibers are ink-free and impurity-free.

From this point onward, the recycled pulp follows the same process as pulp that has been produced from wood.

Paper Machine

In one day an average paper machine makes paper that can span from NY to Miami.



Pulp and Paper Machine

Now that the pulp has been cleaned and bleached, it is ready to be turned into paper.

The next apparatus in the papermaking process is a massive piece of machinery: 20-25 feet wide and longer than a football field that makes a steady stream of paper 350+ days a year. In a day, an average **paper machine** makes paper that can span NY to Miami. It is appropriately named the “paper machine.” Its earliest model was created in 1798 by a Frenchman named Nicholas-Louis Robert. However, the machine is often referred to as a *Foudrinier*, which is the last name of the people who funded the invention, two Englishmen who worked as stationers.

The Papermaking Process

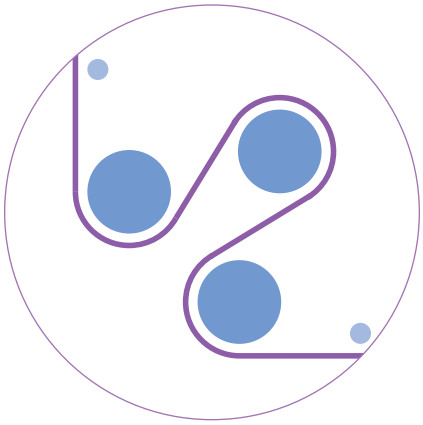
Legend has it that Robert invented the machine because he was tired of listening to the bickering of the workers who performed the various stages of paper production by hand. So he invented the machine to carry out *all* the steps from pulp to dried paper. As such, the paper machine has many different mechanisms within it.

The first step is a stock prep process. Fibers are introduced to a mechanical action (**refining & beating**) to develop pulp for optimal papermaking qualities. The goal is to have a bigger surface area for bonding. Next, it goes into a mixing process — softwood, hardwood, dyes, additives/fillers.

The **headbox** evenly distributes fiber onto the moving, forming fabric. The fabric forms the fiber into a continuous mat. Then, **suction boxes** draw out even more water from the pulp. In just a few seconds, the water content in the pulp has dropped from 99% to about 75%. Now the pulp looks less like a liquid and more like a thin mat. Some engineers call this thin mat the **"paper web."**

In the press stage, the pressure from the rollers encourage the fibers in the paper web to tightly intertwine.

At this stage, the paper is too fragile to move on its own, so it is transferred on top of an absorbent felt. With the supportive felt underneath it, the paper is **pressed** through a series of rollers. As the rollers press down on the paper, the felt acts like a towel, absorbing much of the pulp's water. The pressure from the rollers encourage the fibers in the paper web to tightly intertwine. By the end of the press stage, the water content in the paper is around 45% to 55%.



Dryers

In the drying stage the paper passes through a series of rotating cylinders that emit steam heat.

Next come the **dryers**. The paper passes through a series of rotating cylinders that emit steam heat. After this step, the paper is about 15% water.

Then, the paper is "ironed" in a process called **calendering** to give it a perfectly smooth texture. Finally, the paper is wound into a reel or cut into sheets. It's ready to be packaged and delivered to a store, school or home near you.

Beyond Paper for Printing

Through every process the paper machine executes, highly trained paper machine operators watch control panels to ensure that each mechanism is working correctly. Engineers guide machine operators in fixing any issues that arise.

Of course, the end product of papermaking is not limited to printer paper. Paper is used to create paper cups, paper plates, tissue, corrugated boxes, envelopes, file folders and newsprint. To create these products, the paper goes through a converting process. There are many different types of conversion depending on the end use of the product.

Converting can happen at the same mill where the paper is produced—or it can happen at a stand-alone site that is dedicated to converting. Indeed, the converting industry is a $400-million dollar industry. Three-quarters of paper and paperboard in North America is processed through a converter.

CONVERTERS

Converting refers to the before process that involves cutting, forming, folding and gluing. Converters can add new properties to paper. For example, adding a wax coating to the paper as a water barrier for any food packaging. Converters can also laminate paper to provide it with strength and stiffness. This process is often used on cardboard boxes to enable the end product to act as a shipping container.

Another example of a converter would be an envelope converter. Sophisticated machinery is used to execute converting on paper so that it produces envelopes, stickers, toilet paper, tissues, and other everyday products, at a high volume.

Envelopes are a converted paper product

Writing the Future of Paper

Paper has existed for over 2,000 years, and its story is far from over. As the digital age provides computerized surfaces for us to write on, the role of paper in our creative and intellectual lives comes into greater focus. Many of us find that we prefer to read paper books rather than digital ones, or to brainstorm on paper rather than on a computer screen. These preferences are individual and enable each and every one of us to choose the best medium that suits our needs at any given moment.

SUSTAINABILITY & CONSERVATION

"I love how a rough and tough raw material can be converted into practical uses for everyday life and also improve people's lives."
— Jessica, International Paper employee

For decades, the pulp and paper industry has worked to produce paper in a sustainable manner. Sustainability is a concept that means taking care of the needs of today without compromising the ability of future generations to meet their needs.

As an industry committed to sustainability, the pulp and paper field is constantly looking for ways to create the best paper products while conserving energy, reducing waste and minimizing emissions. It is a field where bright, inventive minds can make a substantial difference to an entire industry by improving systems, machines and processes. It is not an exaggeration to say that the skill, creativity and knowledge of paper engineers can help build a better world. But what do paper engineers actually do?

Paper engineers analyze and design the equipment and processes that are used in paper and paper-product manufacturing. They apply their knowledge of chemistry, biology, physics, math and engineering to improve and invent sustainable manufacturing processes.

What's Next?

Engineers are, first and foremost, problem-solvers. They confront technical problems in the real world and use available materials and resources to solve them. Some engineers are like machine-doctors. They are excellent at identifying weaknesses in machines and improving their performance. Other engineers are more like inventors. They create new systems and machines, or improvements to existing machines.

"There is a lot of troubleshooting and use of critical thinking. It is a dynamic work place where you get challenged every day, you do not get bored."
— Lindsey, International Paper employee

It can be helpful to think of engineering as a field in the same way that medicine is a field. In the medical profession, there are surgeons, general practitioners, and specialists. Similarly, in the engineering field, there are professionals who apply their specialized knowledge in different ways. Mechanical engineers work on the design, improvement and maintenance of machines. Chemical engineers design, improve and oversee chemical processes. Computer engineers develop sophisticated hardware and software. Environmental engineers create effective solutions for the management of environmental waste. All of these different types of engineering talent are needed by the pulp and paper industry.

BECOME A PROBLEM SOLVER

Most people who go into engineering learned about the field through somebody they knew who was an engineer. Sadly, not all of us know an engineer who can tell us about the profession. Many people who might love a career in engineering never find out enough about the field to realize what a good match it might be for them. So, consider it for a moment now. If you like working on machines, or doing experiments in chemistry class; if you enjoy math and science; if you love practical problem-solving; if you want to make the world a better place; you may just be an engineer at heart.

And, you may have a role to play in writing the next chapter in the history of paper!

Career Opportunities in the Paper Industry

A career in pulp and paper engineering can take one all over the world, from managed forests in China, India and Poland, to paper mills in France, Brazil, Morocco and throughout the United States. It may even take you to the headquarters of a Fortune 500 company, like International Paper's headquarters in Memphis, Tennessee.

Starting salaries for engineers in the paper industry are among the highest of any industry. As the table below shows, it is possible for a newly minted college graduate to earn as much as $50,000 to $70,000 in his or her first job.

As of 2017, the demand for engineers to work in the paper industry is greater than the supply.

JOBS

In order to land a job as an entry-level engineer in the pulp and paper industry, you typically need an undergraduate degree in engineering.

JOB	DEGREE REQUIRED	STARTING SALARY	MEDIAN SALARY
Process Engineer	B. Eng.	$58–69,000	$63,000
Reliability Engineer	B. Eng.	$52–72,000	$65,000
Electrical Engineer	B. Eng.	$57–76,000	$66,000
Maintenance Manager	B. Eng.	$63–113,000	$87,000
Mechanical Engineer	B. Eng.	$55–74,000	$69,000
Chemical Engineer	B. Eng.	$60–86,000	$70,000
Project Engineer	B. Eng.	$58–85,000	$72,000

Keep in mind that not all jobs in the pulp and paper industry require a college degree. Machine workers, for example, may or may not be college-educated.

Earnings by Occupation

The table below shows the median pay in a range of jobs within the pulp and paper industry; some requiring a college education and others not. By reaching out to national paper companies, you can find out more about jobs that might suit your ambitions and educational plans.

JOB WAGES	HOURLY	ANNUAL
Cutting and slicing machine setters, operators and tenders	$16.97	$35,300
First-supervisors/Managers of production	$29.07	$60,460
Industrial Production Managers	$46.36	$96,440
Industrial truck and tractor operators	$16.94	$35,240
Paper good machine operators, tenders, setters	$17.56	$36,530

Finally, while engineers are a major profession within the pulp and paper industry, there is also a need for college graduates who want to work in Finance, Management and Information Technology. These jobs are also suited to people who enjoy math and science, love solving real-world problems and thrive in a job that makes a difference.

"I loved learning how not wasteful a paper mill is, to use every part of the tree. The parts that are not used in papermaking are used to power the paper mill."
— Trena, International Paper employee

Educational Opportunities

There are many wonderful educational opportunities in the paper industry. Scholarships are available to high school students who are interested in pursuing Chemical Engineering degrees at the following institutions. It may surprise you to learn that it is possible to major in Paper Engineering at several colleges around the country. These colleges typically have strong ties to the pulp and paper industry which can lead to internships, summer jobs, and eventually full-time employment.

SCHOLARSHIPS

Auburn University
Scholarship Source: Auburn Pulp and Paper Foundation
Bachelor of Engineering
Available to incoming first year students
$1,000 up to full in-state tuition
http://wp.auburn.edu/appf/?page_id=49

Georgia Tech
School of Chemical Engineering
Scholarship Source: Georgia Tech Pulp & Paper Foundation
Bachelor of Engineering
Not available to incoming freshmen. Up to $1,500 in scholarships available to engineering students wishing to earn a Pulp and Paper Certificate
http://osfa.gatech.edu/william-davis-pulp-and-paper-scholarship

Miami University (OH)
Chemical, Paper and Biomedical Engineering Department
Scholarship Source: The Paper Science and Engineering Foundation
Bachelor of Science in Engineering
Available to incoming freshmen
http://miamioh.edu/cec/about/centers-institutes/psef/students/scholarships/williams/index.html

Educational Opportunities

Technical Association of the Pulp and Paper Industries (TAPPI)

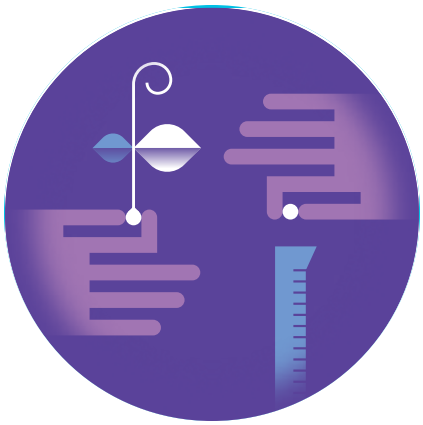
In addition, the paper industry organization TAPPI offers over $140,000 in scholarship funding yearly and has a myriad of opportunities for students pursuing a degree in paper engineering.

North Carolina State
College of Engineering
Scholarship Source: Pulp & Paper Foundation
Bachelor of Science
Available to incoming first year students
Multiple scholarships available for in and out-of-state students
$2,500 up to full tuition
https://cnr.ncsu.edu/fb/undergraduate-programs/scholarships/

The SUNY College of Environmental Science and Forestry
Scholarship Source: Syracuse Pulp and Paper Foundation
Bachelor of Engineering
Available to incoming freshmen who major in Paper Science. Up to $500 per semester for incoming freshmen and increasing with performance up to a total of $25,000 over 4 years
http://www.esf.edu/pbe/sppf/scholarships.htm

University of Maine
Scholarship Source: University of Maine Pulp & Paper Foundation
Bachelor of Engineering
Available to incoming first year students who will study engineering.
Must have a GPA of 3.0 or higher.
$9,000 per year.
https://umaine.edu/chb/undergraduate-programs/5-year-certificate-in-pulp-and-paper-management/

"It wasn't until 12th grade, when I took AP chemistry, that I decided to become a chemical engineer."
— Rachael, REACH Process Engineer at International Paper



The ACS Scholars Program

ACS awards renewable scholarships to underrepresented minority students who want to enter the fields of chemistry or chemistry-related fields. Awards of up to $5,000 are given to qualified students. African American, Hispanic, or American Indian high school seniors or college freshman, sophomores, or juniors pursuing a college degree in the chemical sciences or chemical technology are eligible to apply.

University of Washington
School of Environmental and Forest Sciences
Scholarship Source: Washington Pulp and Paper Foundation
Bachelor of Science in Engineering
Available to incoming freshmen who will major in Bioresource Science and Engineering at UW.
Scholarships of up to $10,000 for first year of study with renewable scholarships throughout college.
http://depts.washington.edu/wppf/scholarships.shtml

University of Wisconsin Stevens Point
Scholarship Source: University of Wisconsin Paper Source Foundation
Bachelor of Engineering
Up to $9,600 over four years
http://www4.uwsp.edu/special/papersciencefoundation/scholarshipProgram.aspx

Western Michigan University
Department of Chemical and Paper Engineering
Scholarship Source: The Paper Technology Foundation
Bachelor of Science
Available to incoming first year students who major in Paper Engineering; the scholarship grows in relationship to a student's academic performance.
$1,000 up to $9,000 per year
https://wmich.edu/papertechfoundation/scholarships

"Coming out of college, students want to be involved quickly and feel like they're making a difference every day. You get that at International Paper."
— Christopher, 4 years at International Paper

Questions & Short Response

Based on your reading of pages 20-33, answer the questions that follow.

1. *The machine that produces pulp is known as?*

2. *Why are logs cut into one-inch chips?*

3. *What is the reason why the pulp used for brown paper bags does not need to be bleached?*

4. *Thanks to efforts to encourage recycling, what percentage of paper is recovered for reuse?*

5. *How does a froth flotation cell de-ink pulp made from recycled paper?*

6. *Can you describe a "paper web"?*

7. *How can wet converting best be described?*

8. *The author points out some of our national heroes were engineers, who were they?*

Questions & Short Response

9. *What are some different types of Engineers?*

10. *Entry-level engineering jobs in the pulp and paper industry command some of the highest starting salaries of all college graduates. What do you conclude from this fact?*

11. *What are some opportunities within the paper industry that make it an attractive career option? Support your answer with two details from the text.*

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