Paper Grades
What is paper (and board)?

Paper is a random web of wood fibers that are bonded mainly with hydrogen bonding.

Hydrogen bonds are reversible, they are weakened when paper is put into water.

When wetted and mechanically agitated, paper falls apart into individual fibers.

This is the basis of paper recycling.
How is paper made?

Wood contains papermaking fibers.

But lignin, a natural adhesive in wood, makes the fibers hard.

The fibers must be liberated from the wood by either chemical or mechanical actions.

Chemical (kraft) treatment

Grinding with metal disks

Unbleached kraft pulp (corrugated boxes)

Bleaching

Bleached Pulp (printing grades)

Mechanical Pulp (yellows with age) (newsprint, magazines)
How is paper made?

- Cylinder Former (One of many vats)
- Fourdrinier Paper Machine
- Yankee Dryer: Creped Tissue
General Grades of Paper and Board

- **Paper**
  - Newsprint
  - Printing and Writing
  - Bags
  - Tissue
  - Towels
  - Napkins

- **Board**
  - Linerboard
  - Corrugating Medium
  - Tubes
  - Drums
  - Milk Cartons
  - Recycled Board (Called Chip Board: Shoebox, Cereal Box)
  - Roofing Felts
  - Fiberboard
Grammage

• Paper, board, and tissue are categorized by the weight per unit area
• Grammage: grams per square meter

• Tissue: typically 15-60 g/m²
• Paper: can range from 30-170 g/m²
• Paperboard: typically greater than 134 g/m²

• Common office copy paper is 75 g/m².

<table>
<thead>
<tr>
<th>Paper Grade</th>
<th>Basis Weight (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tea bag tissue</td>
<td>18</td>
</tr>
<tr>
<td>Oil filter</td>
<td>139</td>
</tr>
<tr>
<td>Toilet Tissue</td>
<td>17</td>
</tr>
<tr>
<td>Vacuum dust bag</td>
<td>42</td>
</tr>
<tr>
<td>Blotting paper</td>
<td>130</td>
</tr>
<tr>
<td>Cigarette tissue</td>
<td>25</td>
</tr>
<tr>
<td>Bond paper</td>
<td>76</td>
</tr>
<tr>
<td>Newsprint</td>
<td>53</td>
</tr>
<tr>
<td>Copy paper</td>
<td>80</td>
</tr>
<tr>
<td>Writing paper</td>
<td>88</td>
</tr>
<tr>
<td>Wrapping tissue</td>
<td>12</td>
</tr>
<tr>
<td>Cardboard</td>
<td>247</td>
</tr>
<tr>
<td>Glassine</td>
<td>36</td>
</tr>
<tr>
<td>Paper Physics Niskanen</td>
<td></td>
</tr>
</tbody>
</table>

Paper Physics Niskanen
TAPPI: TIP 0404-36 Paper Grade Classifications

• A particular grade of paper is typically identified in one or more of the following three ways:
  • Final use of the paper
  • Furnish used in making the paper
  • Type of machinery which was used.

• Example: “off-machine coated groundwood publication paper”

• 100’s of specific paper grades

• 12 major grades are in common usage and represent over 95% of all paper tonnage produced
## Global Paper and Board Consumption, 2015

<table>
<thead>
<tr>
<th>Grade Consumption 2015</th>
<th>Thousand Tonne</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and Board</td>
<td>410,794</td>
<td>100</td>
</tr>
<tr>
<td>Newsprint</td>
<td>24,104</td>
<td>6</td>
</tr>
<tr>
<td>Printing &amp; Writing</td>
<td>102,188</td>
<td>25</td>
</tr>
<tr>
<td>Uncoated Woodfree</td>
<td>52,841</td>
<td>13</td>
</tr>
<tr>
<td>Coated Woodfree</td>
<td>25,063</td>
<td>6</td>
</tr>
<tr>
<td>Uncoated Mechanical</td>
<td>11,758</td>
<td>3</td>
</tr>
<tr>
<td>Coated Mechanical</td>
<td>12,526</td>
<td>3</td>
</tr>
<tr>
<td>Packaging Paper and Board</td>
<td>231,569</td>
<td>56</td>
</tr>
<tr>
<td>Containerboard</td>
<td>157,417</td>
<td>38</td>
</tr>
<tr>
<td>Cartonboard and Other Paperboard</td>
<td>57,932</td>
<td>14</td>
</tr>
<tr>
<td>Wrapping Paper</td>
<td>16,220</td>
<td>4</td>
</tr>
<tr>
<td>Tissue</td>
<td>34,947</td>
<td>9</td>
</tr>
<tr>
<td>Other Paper and Board</td>
<td>17,985</td>
<td>4</td>
</tr>
</tbody>
</table>
Uncoated groundwood:

• Uncoated mechanical pulps, could be TMP or other... not necessarily groundwood
• 80% is newsprint
• 24-75 g/m² with newsprint 40-50 g/m²
• Directory, computer paper, catalog, advertising supplements
• Needs to be cheap, strength, brightness, bulk, ink receptivity
Coated groundwood:

- At least 10% mechanical pulps, typically 50-55%, balance chemical pulp
- Finished sheet grammage of 45-130 g/m²
- Letterpress, offset, light weight coated (LWC), and magazine.
- 70% of magazines are this grade
- Needs to be cheap, strength, brightness, bulk, ink receptivity
### Coated Publication Grades

**Table 20-5. Characteristics of coated publication grades.**

<table>
<thead>
<tr>
<th>General characteristics</th>
<th>Typical use</th>
<th>Base stock</th>
<th>Coating</th>
<th>Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1. Enameled,</td>
<td>Annual reports</td>
<td>High-brightness chemical pulp</td>
<td>High in TiO₂</td>
<td>82-88</td>
</tr>
<tr>
<td>double-coated,</td>
<td></td>
<td>Heavily filled</td>
<td>High gloss</td>
<td></td>
</tr>
<tr>
<td>hand-sorted, expensive</td>
<td></td>
<td></td>
<td>Enameled</td>
<td></td>
</tr>
<tr>
<td>base and coating; high</td>
<td></td>
<td></td>
<td>Synthetics</td>
<td></td>
</tr>
<tr>
<td>gloss; basis weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>above 70 lb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 2. Double-coated,</td>
<td>Expensive advertising</td>
<td>High-brightness chemical pulp</td>
<td>High in TiO₂</td>
<td>78-82</td>
</tr>
<tr>
<td>expensive base and</td>
<td></td>
<td>Filled (clay)</td>
<td>Some clay</td>
<td></td>
</tr>
<tr>
<td>coating</td>
<td></td>
<td></td>
<td>Synthetics</td>
<td></td>
</tr>
<tr>
<td>No. 3. Single- or</td>
<td>Advertising</td>
<td>Chemical pulp</td>
<td>Mostly clay,</td>
<td>76-82</td>
</tr>
<tr>
<td>double-coated lower</td>
<td></td>
<td>Minor amounts of</td>
<td>some TiO₂</td>
<td></td>
</tr>
<tr>
<td>quality basesheet</td>
<td></td>
<td>groundwood</td>
<td>Less expensive</td>
<td></td>
</tr>
<tr>
<td>No. 4. Lower cost,</td>
<td>Magazine</td>
<td>Groundwood and chemical pulp,</td>
<td>Less expensive</td>
<td>72-78</td>
</tr>
<tr>
<td>lower brightness</td>
<td></td>
<td>some clay filler</td>
<td>Coating — clay and TiO₂</td>
<td></td>
</tr>
<tr>
<td>No. 5. Lower basis</td>
<td>Directories,</td>
<td>Mostly groundwood or TMP,</td>
<td>Variable, some</td>
<td>68-72</td>
</tr>
<tr>
<td>weight, high</td>
<td>catalogs,</td>
<td>chemical pulp for runnability</td>
<td>contain synthetics</td>
<td></td>
</tr>
<tr>
<td>groundwater content</td>
<td>magazines</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Coating color – the term used for the coating when in the slurried state before application to the paper, even if white.

- A coating color is typically about 50-70% solids.
- The coating color is applied so that the coating forms a 4 to 8 lbs./3000 ft² (6.5 – 13 g/m²) per side on the sheet.
- The dried coating may form up to 30% of the total weight of paper.
- Coatings improve smoothness, gloss, opacity and printability.
Coating Formulation

• Three main components to a coating color:
  • Water
    • Function is to serve as a vehicle for the coating components
  • Pigment (typically clay or calcium carbonate)
    • Function is to provide color, opacity, and smoothness to the surface
  • Binder (typically latexes or starch)
    • Function is to make the coating layer strong
Coating Formulation

• All but the simplest formulas will have additional components known as *additives* such as:
  • Flow modifiers
  • Colorants
  • Optical Brighteners
  • Defoamers
  • Dispersants
  • Preservatives
  • Etc.

• It is not uncommon for coating formulations to have 10-15 components.
Uncoated wood-free:

- Less than 10% mechanical pulp, normally 0%
- Not coated
- Office papers (forms, copy, bond, tablet, and envelope), carbonless, and printing papers (offset, cover, text).
- Other names: printing, writing, and book papers.
- Needs exact color/whiteness/brightness, smoothness, ink receptivity, surface strength, stiffness

<table>
<thead>
<tr>
<th>Grammage g/m²</th>
<th>Basis weight by lb/17x22 in by 500 sheets</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>13</td>
</tr>
<tr>
<td>60</td>
<td>16</td>
</tr>
<tr>
<td>75</td>
<td>20</td>
</tr>
<tr>
<td>90</td>
<td>24</td>
</tr>
</tbody>
</table>
Coated wood-free:

• Less than 10% mechanical pulp, normally 0%
• Magazines, books, and commercial printing.
• 70 g/m² to 170 g/m² for the finished sheet.

• Needs exact color/whiteness, smoothness, ink receptivity, surface strength, stiffness
Kraft Paper

• Unbleached or bleached kraft pulp
• 50 g/m2 to 134 g/m2.
• Wrapping, bag/sack, shipping sack, and other converting (such as saturating and cable)
• High tensile and tear strength
Bleached paperboard

• Bleached kraft pulps primarily
• About half is coated
• Generally above 134 g/m², typically from 200 g/m² to 500 g/m².
• Primarily folding carton and milk carton.
• Also included: cups, plates, printing boards, tag stock, computer cards, file folders, and index cards.
• Needs stiffness, strength, barrier properties
Unbleached paperboard

- Unbleached and made from virgin kraft or neutral sulfite semichemical pulp
- Also may have recovered paper as a feedstock
- 130 g/m² to 450 g/m²
- Primarily linerboard for corrugated containers. Typically: 205 g/m² or 42 lb/1000 ft²
- Also included in this is corrugated medium, made with semi-chemical and often some amount of recycled. Typically 9 point medium, 125 g/m² or 26 lb/1000 ft²
- Needs strength, burst, stiffness, tensile, water resistance
Recycled paperboard

- Sometimes called chipboard.
- Made entirely of recovered paper, often newspapers and low valued recovered papers.
- Often made on a multi-cylinder machine.
- Have greyish color since not deinked.
- Used often to make solid fiber boxes that require low strength --- make up with thickness.
- Grades include corrugating medium, folding boxboard (clay coated), setup boxboard (uncoated), and paperboard.
- Also included are gypsum liner, core tube stock, and roofing felt.
- Needs to be cheap, substitute thickness for fiber strength properties.
MG kraft specialties:

• Machine glazed finish, high gloss
• Made by allowing the coating to dry on a large, chrome plated dryer with polished surface
• Grades include wax base, wrapping, carbonizing, and kraft specialties.
Tissue

• At home: bleached chemical pulps
• Away from home: recovered paper
• Manufactured on Yankee machines with either a wet or dry crepe operation
• 20 g/m² to 75 g/m²
• Primarily tissue, towel, bathroom, napkins, etc.
• Also: wrapping tissue, tracing tissue,
• Soft, bulky, absorbent, moderate strength
Market Pulp

- Pulp is typically bleached hardwood or softwood kraft pulp
- Deinked market pulp also exists
- Wet lap (50% solids) or dry lap (80-85% solids)
- Unbleached or mechanical pulp grades are not common
- Sold in sheets, bales or rolls
- Needs to have HW or SW, cleanliness
- Fluff pulp is a special type of market pulp, typically bleached kraft pulp that is made to be processed in a hammer mill to produce fluff suitable for diaper or other personal care products
- Dissolving pulp is a special type of pulp, high purity, very high cellulose content used to make cellulose derivatives, e.g., cellulose acetate
Other

• Grades that do not fit conveniently in other categories
• Less than 5% of all paper or board
• Examples are hardboard, asbestos board, thin papers (cigarette tissue, condenser, bible), and dense papers (glassine, grease proof, release, and vegetable parchment).
### Basis Weight – Units – lbs.

- mass or weight of paper per unit area.

<table>
<thead>
<tr>
<th>Grade of Paper</th>
<th>Sheet Dim. (in.)</th>
<th>No. of Sheets in Ream</th>
<th>Square Feet Per Ream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing and Printing</td>
<td>17 x 22</td>
<td>500</td>
<td>1298.6</td>
</tr>
<tr>
<td>Paperboard</td>
<td></td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>Wrapping</td>
<td>24 x 36</td>
<td>480</td>
<td>2880</td>
</tr>
<tr>
<td>Book</td>
<td>25 x 38</td>
<td>500</td>
<td>3298.6</td>
</tr>
<tr>
<td>News/Tissue</td>
<td>24 x 36</td>
<td>500</td>
<td>3000</td>
</tr>
<tr>
<td>Bag</td>
<td></td>
<td></td>
<td>3000</td>
</tr>
</tbody>
</table>

SI or International Units are grammage (grams/meter²).

20 lb copy paper = 75 g/m²
Thickness or Caliper

- The dimension of the paper in the Z-Direction (out of plane).
- Units are:
  - mils = points (pts) = 1/1000 inch
  - millimeters = 1000 micrometers (µm)
  - To convert from mil to micrometer, multiply by 25.4

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness (microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Towel Tissue</td>
<td>200</td>
</tr>
<tr>
<td>Copy Paper</td>
<td>100</td>
</tr>
<tr>
<td>Newsprint</td>
<td>70</td>
</tr>
<tr>
<td>Board for dry wall</td>
<td>350</td>
</tr>
</tbody>
</table>
Apparent density: the mass divided by the volume

Apparent Bulk: the volume divided by the mass

<table>
<thead>
<tr>
<th></th>
<th>Density</th>
<th>Bulk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/m³</td>
<td>m³/mt</td>
</tr>
<tr>
<td>Tissue</td>
<td>281</td>
<td>3.56</td>
</tr>
<tr>
<td>Napkin</td>
<td>355</td>
<td>2.82</td>
</tr>
<tr>
<td>Liner Board</td>
<td>698</td>
<td>1.43</td>
</tr>
<tr>
<td>Newsprint</td>
<td>704</td>
<td>1.42</td>
</tr>
<tr>
<td>Copy Paper</td>
<td>778</td>
<td>1.29</td>
</tr>
</tbody>
</table>
Moisture Content  The mass of water divided by the total mass of the initial sample (i.e. the wet mass) times 100 %.

<table>
<thead>
<tr>
<th></th>
<th>Towel Tissue</th>
<th>Copy Paper</th>
<th>Newsprint</th>
<th>Board for Gypsum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Air dry mass, g</strong></td>
<td>A</td>
<td>0.39</td>
<td>.78</td>
<td>1.82</td>
</tr>
<tr>
<td><strong>Oven dry mass, g</strong></td>
<td>O</td>
<td>0.36</td>
<td>.73</td>
<td>1.67</td>
</tr>
<tr>
<td><strong>Moisture Content, %</strong></td>
<td>MC</td>
<td>7.7</td>
<td>6.4</td>
<td>8.2</td>
</tr>
</tbody>
</table>

MC = 100% * (A - O) / A
Moisture Content

- Hysteresis, the MC depends on the direction.
- All mechanical properties depend on moisture content.

Figure 3. Moisture content vs. relative humidity in a chemical pulp and a groundwood at $T = 50^\circ$C.
Selected Optical Properties

- Brightness is a measurement of the reflectivity of a material at a wavelength of 457 nm (the blue region) or $R_{\infty}$ at 457 nm.

- Opacity determines the ability of a material to prevent light from transmitting through it.
  - Printing opacity is $Ro/R_{\infty}$

- Gloss determines the amount of specularly reflected light coming from the surface.

- Color: the quality of an object with respect to light reflected by the object, usually determined visually by measurement of hue, saturation, and brightness of the reflected light.

- $Ro$ is the light reflectance of a single sheet of paper with black backing
- $R_{\infty}$ is the light reflectance of an infinite stack of paper
Selected Strength Properties

- **Tensile strength**: ultimate force to break paper in tensile
  - Breaking length: length of paper that can have its weight supported
  - 8-10 km for bleached softwood
  - 20 km for pine
  - 4.5 km for steel

- **Tear strength**: energy required to propagate a tear through paper for a fixed distance

- **Burst Strength**: amount of hydrostatic pressure to rupture a surface of paper
  - Uses a rubber bladder to puncture paper
Selected Strength Properties

- Folding Endurance: number of double folds a 15 mm wide paper can endure before failing in tensile under a 1 kg load.

- Stiffness (STFI) edgewise compression strength test.

- Stiffness (Taber): bending moment of a 1.5 in wide paper at 15 degrees from center.