Unit 20 · Paper and Pulp

ANSWER KEY · FOR TEACHERS

Full marks 37

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. cellulose
2. lignin
3. pulp
4. bast
5. digester
6. sizing
7. fillers
8. GSM

Each carries 0.5 mark. **K · 4**

2 Label the diagram

1. debarking drum
2. chipper
3. white liquor NaOH + Na_2S
4. washer

Each carries 0.5 mark. **K · 2**

3 Multiple choice

i. **a.** softwood such as pine **K · 1**

Softwood fibers are about 3–4 mm long and give strength; hardwood fibers, about 1 mm, give smoothness; straw and recycled fibers are short.

ii. **b.** dissolves the lignin and much of the hemicellulose **U · 1**

Mechanical pulping keeps everything, lignin included; the kraft cook dissolves about half the wood, which leaves as black liquor.

iii. **c.** optical brightening agents **K · 1**

Optical brighteners absorb invisible ultraviolet light and give it out as blue light, which hides the paper's yellowish tint.

iv. **b.** the alum used in sizing is acidic and slowly breaks the cellulose chains **U · 1**

Rosin–alum sizing left the paper slightly acidic, and in damp air the acid breaks the cellulose chains.

v. **d.** lokta paper **A · 1**

Lokta's long bast fibers, made without acidic alum sizing and resistant to pests, last for generations; newsprint keeps its lignin and yellows.

4 Short answers

a. **MARKING SCHEME** **U · 2**

- ✓ Pressed close and dried, the –OH groups of neighboring cellulose fibers form hydrogen bonds, billions of them.
- ✓ Water forms hydrogen bonds with the –OH groups itself and pushes between the fibers, so they let go of each other.

b. **MARKING SCHEME** **U · 2**

- ✓ Cellulose, hemicellulose and lignin.
- ✓ Lignin is removed: it glues the fibers together in wood and yellows paper.

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c. MARKING SCHEME U · 2

- ✓ They grow back quickly (bamboo every few years), so no forest is cut for them.
- ✓ Bagasse and straw are wastes of crops grown anyway; using them keeps them from being burned in the fields.

d. MARKING SCHEME A · 2

- ✓ Newsprint is mechanical pulp, which keeps nearly all the wood's lignin.
- ✓ Light and air change lignin into yellow compounds; book paper is chemical pulp with most of its lignin removed.

e. MARKING SCHEME U · 3

- ✓ Headbox and wire: the stock spread on a moving mesh, water draining off, a wet mat formed.
- ✓ Press and dryer sections: water squeezed out, then evaporated on steam-heated cylinders.
- ✓ Calender and reel: the sheet pressed smooth and wound up.

5 Long answer

ANSWER U · 4

Mechanical pulping grinds logs against a grindstone, or tears chips between ribbed discs, with few or no chemicals; nothing is removed, so the yield is about 90–95%, but the fibers are cut short and the lignin stays, so the paper is weak and yellows (newsprint).

Chemical (kraft) pulping cooks the chips in a digester with NaOH and Na_2S at about 170 °C under pressure; the lignin and much hemicellulose dissolve, so the yield is only about 45–50%, but the fibers stay long and strong, and the paper is durable.

The black liquor (the dissolved lignin and spent chemicals) is burned in a recovery boiler: it makes steam and electricity, and the NaOH and Na_2S are recovered for the next cook.

MARKING SCHEME

- ✓ How each frees the fibers: grinding against cooking in NaOH + Na_2S.
- ✓ Yield: about 90–95% against 45–50%, because the lignin stays or is dissolved.
- ✓ The paper: weak and yellowing against strong and durable.
- ✓ Black liquor burned for energy, and its chemicals recovered.

6 Numerical problems

a. ANSWER A · 4

i. Area of one sheet = 0.200 m × 0.250 m = 0.0500 m^2; of 100 sheets 5.00 m^2. GSM = 350 g ÷ 5.00 m^2 = **70 g/m²**.

ii. 70–80 GSM is **standard-quality** office and writing paper: notebooks, books, office printing.

iii. Mass = 250 g/m^2 × 1/16 m^2 = **15.6 g**.

MARKING SCHEME

- ✓ Area 5.00 m^2.
- ✓ 70 GSM.
- ✓ Standard-quality writing and office paper.
- ✓ 15.6 g.

b. ANSWER A · 4

i. Pulp = 0.48 × 12.0 t = **5.76 t**.

ii. Pulp = 0.93 × 12.0 t = **11.2 t** (nearly twice as much, but weaker and yellowing).

iii. Pulp is 90% of the paper, so paper = 5.76 t ÷ 0.90 = 6.40 t = 6.40 × 10^6 g. Sheets = 6.40 × 10^6 g ÷ 5.0 g = **1.28 × 10^6 sheets** (about 1.3 million).

MARKING SCHEME

- ✓ 5.76 t of kraft pulp.
- ✓ 11.2 t of mechanical pulp.
- ✓ 6.40 t of paper.
- ✓ 1.28 × 10^6 sheets.

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7 Think

ANSWER HA · 3

A sheet holds together by hydrogen bonds where fibers touch and overlap. Each pulping and beating cuts and wears the fibers, so after about five to seven times they are too short to overlap enough, and the sheet is weak or falls apart. Fresh softwood pulp has long fibers (3–4 mm) that reach across many short ones and bond to them, giving the sheet back its strength.

MARKING SCHEME

- ✓ Strength comes from fibers overlapping and hydrogen-bonding to each other.
- ✓ Recycling shortens the fibers, so after about five to seven times they are too short to hold a sheet.
- ✓ Long softwood fibers bridge the short ones and restore the strength.

8 Activity: Five papers

(not marked)

WHAT STUDENTS SHOULD FIND

Lokta and the notebook page show long fibers at the torn edge; newspaper and tissue tear easily with short ones. The drop soaks in and spreads on tissue (unsized), stays as a bead for a while on the sized notebook page and the coated magazine page. The newspaper yellows in the sun, because mechanical pulp keeps its lignin; the notebook page, magazine and lokta change little.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	8	15	11	3	**37**

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