A Wood, Metals and Plastics, A2 Man and Production in Practice

Simulation of Papermaking

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Recommended year	*5th grade or more*
Time framework	*2-3 lessons + 1-2 weeks to process the project (optional)*
Thematic block	*Man and Production in Practice*
Objectives and development of competencies	*Pupils will manage to make according to the instructions a sheet of paper, which is a commonly used material during the lessons of technology as well as in daily use. They will be able to compare characters of different paper samples. Based on experience gained during solving practical tasks, pupils will be able to describe basic stages of paper production in simple way. They will be capable to give examples of its use in daily life. Pupils will manage basic laboratory operations (measuring, weighing, filtrating), following the hygienic rules and work safety.*
Interdisciplinary (cross-curricular) relations	*Mathematics – to calculate surface area, area weight* *Information and Communication Technologies – searching and processing information*

Theoretical Introduction

Paper and paper products represent one of the mass produced consumer commodities. On a global scale, it is exceeded only by building materials, motor oils and steel. The world paper production is comparable with the plastic one. Therefore it is suitable to implement a model of paper product making into lessons, because pupils know this material from their daily routine.

The current world paper and cardboard production achieves 400 mil tons, the average consumption is about 55 kg per inhabitant per year. The paper consumption points out the material and cultural level of society. Both, paper and cardboard, is used e.g. for packaging, hygienical use, writing and printing ("graphic paper").

The lack of school interpretation of paper production is in missing demonstration of its production principle, which is based on mechanical operations and pupil can understand it in their 5^{th} grade. Pupils often do not understand paper production even when they visit a paper mill, because the modern production procedures are complicated and "not transparent".

The principle of paper production is really easy to model in school conditions and it needs no special facilities or material requests, unlike the other materials which pupils are in contact with. The basic activity for practical tasks models the industrial production based on mechanical processes. This activity represents manual operations for pupils and leads them to improve their handicraft. Pupils can work and follow the simpler procedure, which models the classical manual paper production, or the mechanical production, which includes manual operations too. The extra proposed tasks are optional and they just supplement the basic tasks which are focused on mechanical paper sheet making only. These models illustrate the production with special characters (colour paper) and follow-on the evaluation of paper, its characters.

Methodical part for teachers

Objectives: to introduce principles of industrial paper production to pupils via practical tasks.

The principle of paper production process

Paper is made by felting, de-watering and drying fibres from their water suspension (fibre mash) called **pulp**. The paper fibre raw material (pulp – see the fig. 1) includes cellulose, substance with large molecules. Pulp is formed by wet defibering and grinding fibre materials, in some cases additives are put into to improve paper characters.

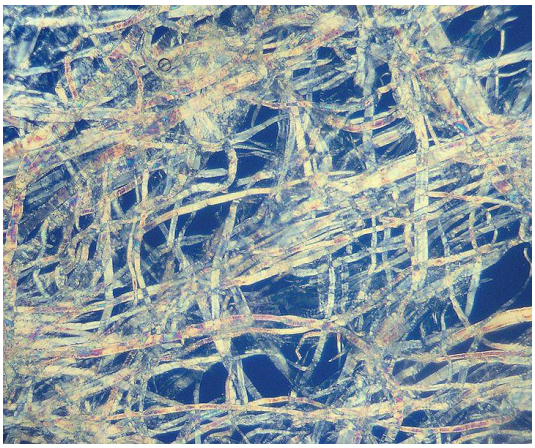


Fig. 1 **Pulp** – 200x multified
(source: https://cs.wikipedia.org/wiki/Soubor:Zellstoff_200_fach_Polfilter.jpg)

Defibering and material grinding causes namely splitting bonds of cellulose fibres. It can be liken to unweaving ropes until you get tiny fibres with large specific surface (fig. 2a), which are quite tightly fixed together in dry paper (fig. 2b). On the contrary, when paper is wet, water spreads between fibres (fig. 2c). That leads to releasing the texture, because water gets fixed to fibre surface easily. That process explains why wet paper is so disbanding.

The pulp additives vary according to the paper types. Currently, there is large scale of them. Most papers include **sizing agent** on resin basis or based on synthetic materials, which "makes the fibre surface sticky". The sizing process increases the water resistance of paper. Many papers, especially the ones used for printing, contain **filling agent** (e.g. kaolin), to alter various characters, among other things it increases the paper porousness. To get coloured paper, there are **pigment or dye** solutions that bind to the fibre surface. Until the end of 18th century, paper was made by shovelling and filtering of fibres using a manually controlled screen (this "**vat** paper" is nowadays considered to be a luxurious product). These days, the majority of paper is made on nonstop working machines called paper mills.

The diluted pulp with 99% of water is poured on the wet part of the paper mill. **Pulp dewatering and fibre felting processes** usually run on a never ending longitudinal screen (the analogy of a belt conveyor) with transverse vibrations. First, there is sedimentation (filtration), then underpressure (exhaustion). The wet paper stripe is pressed with the felted fabric between drums and then it gets dried on them by max. heat of about 70-120 °C. Most of water disappears in **the drying part** of the mill and the fibre system is created, see the fig. 2b. In the drying part of the machine, there is also finishing the process of sizing by melting down the minims of sizing agents.

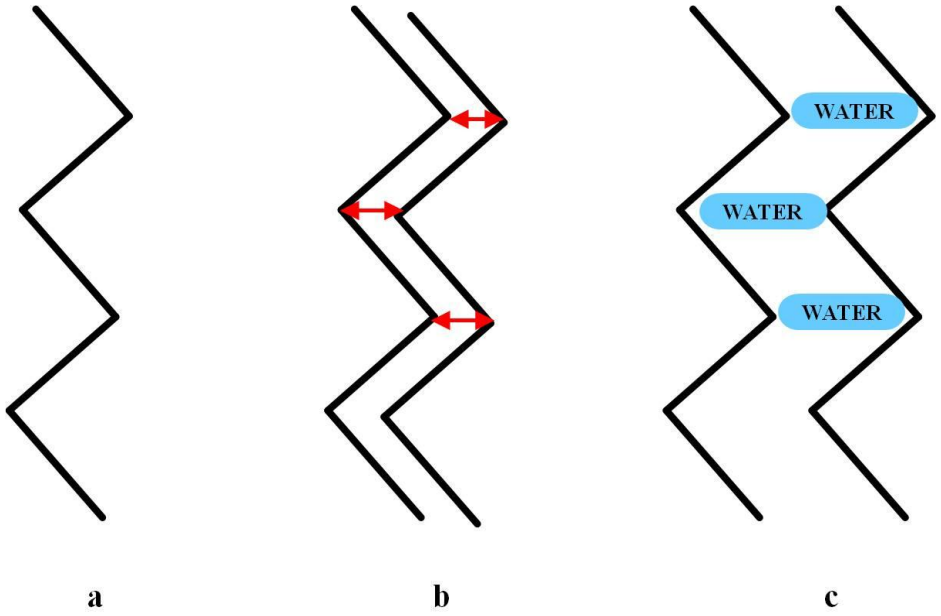


Fig. 2 **Bindings in paper;** a – cellulose fibre, b – cellulose fibres in dry paper, c – cellulose fibres in wet paper

The teacher holds a discussion with pupils in the introduction part of the lesson. The pupils give examples of paper use in their lives, name the types of paper they know. During the discussion, the teacher shortly introduces the basic stages of the paper production process. The core of the lesson consists in practical tasks, which should help pupils to understand the principle of paper production.

There are altogether 8 activities attached. The tasks 1-4 are models variants of paper production, the 5th task is focused on the paper characters monitoring, other tasks or activities are optional.

The teacher selects the activities in consideration of his school material equipment, the amount of lessons and age of pupils. At least 2 activities should be implemented for the topic, regardless the conditions mentioned above – paper sheet making and evaluating its characters.

Task list:

1. Papersheet making
2. Coloured papersheet making
3. Model of "vat paper" production
4. Model of coloured "vat paper" production
5. Evaluation of paper characters
6. Papersheet size determination
7. Paper area weight determination
8. Project on the topic „PAPER"

See the table 1 to check all the tasks and necessary equipment.

Table 1 **Tasks overview** – lesson implementation, equipment requests

Task no.	Recommended year	Time framework	Teaching place	Tools	
1	5th grade or more	45 min	an ordinary classroom with waterpiping to connect a water pipe	pulp (filter paper, sanitary pulp, white "cellulose" toilet paper, Aqua Tube Zewa …), scissors, a beaker (250-500 cm^3), a glass stick, an immersion blender, filter paper, a Büchner funnel (diameter 9-12,5 cm), a filter flask (500-1000 cm^3), a water pump, a roller	**papersheet making**
2	5th grade or more	45 min	an ordinary classroom with waterpiping to connect a water pipe	the same like in no. 1 + pigment/dye (ink, blueberry or raspberry sauce, rose mallow fruit tea …)	
3	5th grade or more	45 min	an ordinary classroom	pulp (filter paper, sanitary pulp, white "cellulose" toilet paper, Aqua Tube Zewa …), scissors, 2 beakers or glasses (250-400 cm^3), a tea spoon, plastic or metal tea strainer (diameter 6-8 cm), any heat power (drying place, heater, hot steam oven, hair dryer…)	
4	5th grade or more	45 min	an ordinary classroom	the same like no. 4 + pigment/dye (ink, blueberry or raspberry sauce, rose mallow fruit tea …)	
5	5th grade or more	15-20 min	an ordinary classroom	paper samples (made in the previous tasks), blue ink, redipen (top point diameter 0,5-2 mm), a pen holder, a beaker (250-500 cm^3), filter paper	**evaluation of paper characters**
6	5th grade or more	10-15 min	an ordinary classroom	a sheet of paper size A4, a ruler (30 cm), calculator	**optional tasks**
7	5th grade or more	10-15 min	an ordinary classroom	printing paper, drawing paper, cardboard …, a ruler, a calculator, scales	
8	5th grade or more	1-2 weeks	a long term homeproject		

Alternative “with tools“

The alternative for better equipped schools concerns the tasks no. 1, 2, 5-8.

The task notes:

Task no. 1 – **Papersheet making** and **2** – **Coloured papersheet making** are assigned to younger pupils to show them the basic procedure of papersheet making. The pupils make a white sheet of paper in the first task and a coloured sheet in the second one. They work in groups of two or five. It is possible to choose just one of the tasks, but it is preferable to implement both regarding the following task of paper evaluation (task no. 5). Each of the group completes one of the tasks. According to the size of the Büchner funnel used, calculate the needed amount of pulp. You will need about 0,8 g of pulp for the area surface 1 dm^2, that is more or less like filter paper with its size 8x8 cm or a piece of sanitary pulp (available at drugstores or health care shops) with its size 8x5 cm. You should weigh the amount of toilet paper or the roll Aqua Tube of Zewa toilet paper before. Prepare a template from cardboard before the lesson, pupils will copy it and cut a pad from filter paper to insert it into the Büchner funnel (see the fig. 3). Leave a paper jut on the pad to make it easier to take the papersheet out of the funnel. The last stage of paper making is drying process. If you have no drying room nor hot steam oven nor heater available, you can leave the papersheet to air-dry till the next lesson.

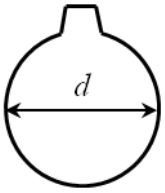
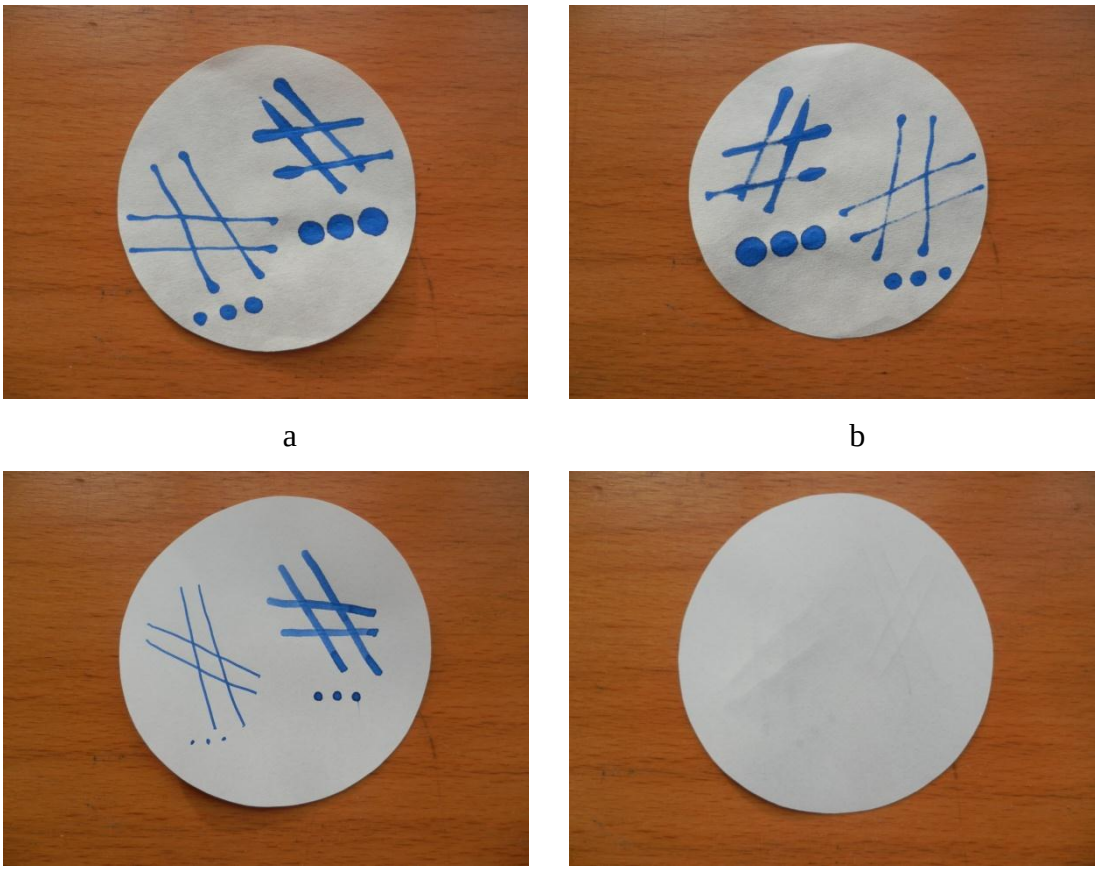


Fig. 3 **Paper pad for Büchner funnel**

Papersheet making (white or coloured) covers 1 lesson. You can continue next lesson with the **task no. 5 – Evaluation of paper characters**. Pupils compare the characters of sized and non-sized, white and coloured paper. They compare their own made samples of non-sized paper with the samples of sized paper from a shop. They may use e.g. ordinary writing paper or copy paper. The fig. 4 illustrates the comparison of sized and non-sized paper, the thinner lines correspond to redipen with its top point 0,5 mm, the thicker lines to the top point 2,5 mm.



a b

c d

Fig. 4 **Comparison of sized and non-sized paper**
a – nonsized paper, face; b – nonsized paper, back; c – sized paper, face; d – sized paper, back

Tasks no. 6 and **7** are solved by each pupil individually and these are obligatory to mastering the topic.

The decision, whether **task no. 8** (a project) shall be obligatory or voluntary, is just and only up to a teacher as well as its form of processing and focus points.

Alternative “no tools“

The alternative for poorly equipped schools concerns the tasks no. 3-8.

The task notes:

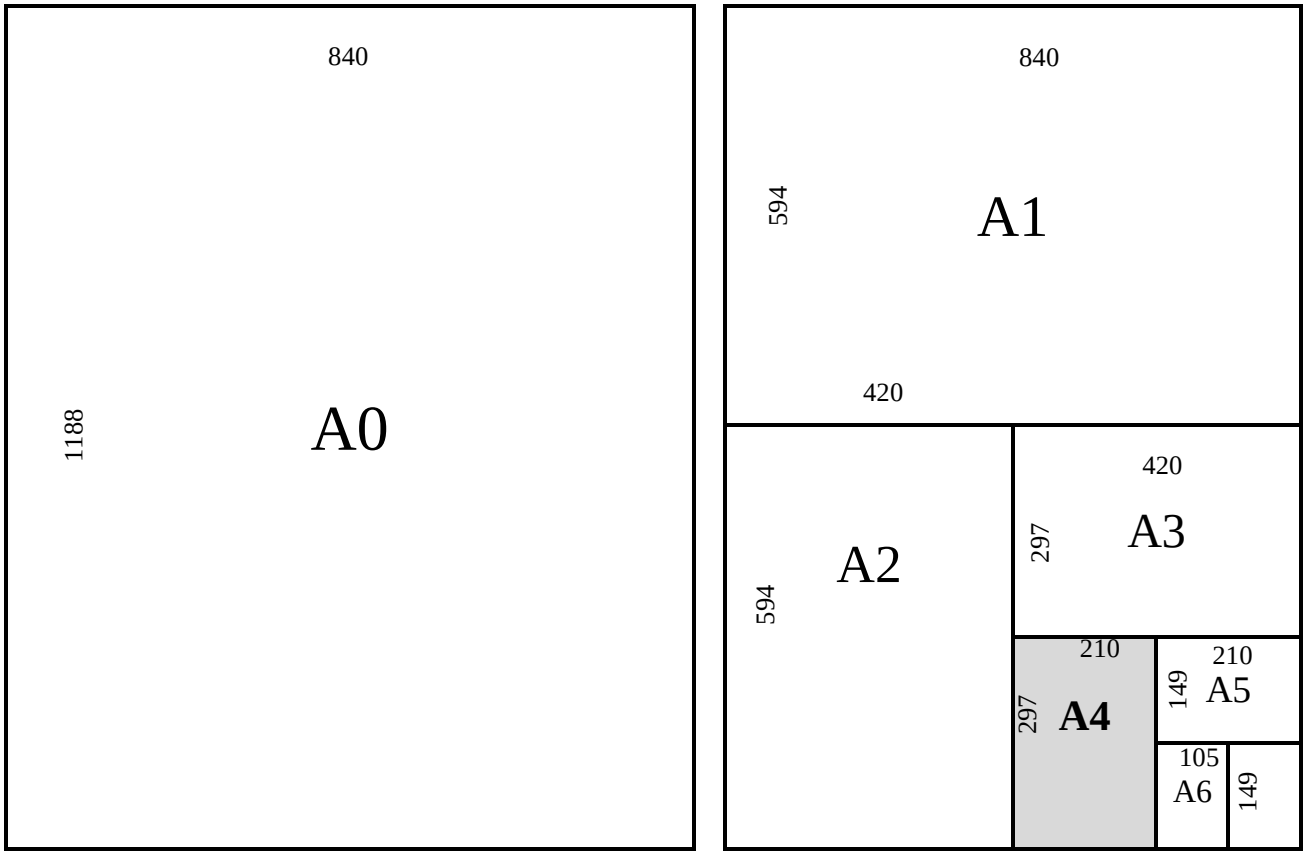
Task no. 3 – **Model of “vat paper” production** is actually the task no. 1 in its simplified version. The recommended procedure can be implemented in an ordinary classroom even with its minimal equipment (see the table 1). In such a case, even any immersion blender or pump is not necessary. Cut the pulp carefully to really small pieces. The ideal source material is a roll Aqua Tube of Zewa toilet paper which falls apart in contact with water. Pour the pulp directly through the screen so that its surface is covered with it all around. When it gets

drained, put 2-3 paper pads on the pulp and press (see the fig. 3). That will help to take a wet paper sheet out of the screen.

Task no. 4 – Model of coloured "vat paper" production is a simpler variant of the task no. 2. Follow the same recommendations like in the previous task. It is recommended to divide the tasks so that a part of pupils prepare a white sheet of paper, the other part a coloured sheet, exactly like in the tasks 1 and 2.

The instructions to the tasks 5-8 are the same for both of the alternatives (for better or poorly equipped schools).

Solution of task no. 6



An **excursion** to manual paper production is productive bonus to the topic, pupils may watch its production process and facilities which are simple and complies with our practical tasks. In Central East Europe region, you can find several manufactures for vat paper, which are usually marked as protected technical monuments. These often look like museum expositions and most of the time they are set out for school excursions too. That forms ideal conditions for schools in that area. However, further located schools can schedule this excursion like a school trip.

Selected examples of vat paper production manufactures:

- the Czech Republic: Ruční papírna Velké Losiny – http://www.rpvl.cz/en
- the Slovak Republic: PETRUS papier, Prietrž, Senica region http://www.rucnypapier.sk/index.php?lang=en&op=exkurzie
- Germany: Technisces Museum Papiermühle Niederzwonitz (Sachsen) – http://www.zwoenitz.de/stadtleben/kultur-freizeit/museen/papiermuehle/

Used literature and references

[1] https://cs.wikipedia.org/wiki/Soubor:Zellstoff_200_fach_Polfilter.jpg
[2] Blažej, A., Krkoška, P.: *Technológia výroby papiera*. Alfa, Bratislava 1989.
[3] Hnětkovský, V.: *Zkoušení papíru*. SNTL, Praha 1977.

Attachments

PAPER AND ITS PRODUCTION

Paper consists of cellulose fibres. **Cellulose** is organic material and it is the main structural component of plant cells. It is formed by large molecules which are compounded into small fascicles and those are interconnected to form cellulose fibers.

The basic material in paper production is so called **pulp**, which contains except cellulose also other materials in small volume. Pulp is acquainted from wood or annual plants (grasses or others) by the combination of mechanical and chemical processes.

Until the end of 18th century, paper was made manually and the vat paper is considered to be a luxurious product nowadays. These days, the majority of paper is made on nonstop working paper mills.

The production may be divided into four stages.

1. pulp preparation and formation
2. de-watering
3. pressing
4. drying

Pulp preparation and formation

The first stage process is **defibering** and **grinding** to get water suspension (fibre mash) called pulp. According to the paper types, there are added various additives. Examples of additives are: **sizing agents,** which increases the water resistance of paper among other effects, **pigments or dye** solutions in case of coloured paper or **filling agents** (e.g. kaolin), to make easier printing processes.

De-watering

Pulp is mixed with water and poured on a vibrating screen of a paper mill, where it gets rid of the water. Water starts leaking and drains based on the gravity law, more water is then pumped out by vacuum.

Pressing

A wet stripe of paper is pressed between drums and felted fabric.

Drying

Paper is dried on heated drums at the temperature over 100 °C. In this stage, the excess water is pumped out and also sizing process finishes, because the higher temperature melts the smallest elements of the sizing agents.

Fig. 5 is a scheme which illustrates the activity models of all paper production stages. The following practical tasks are morels of paper production. Pupils learn about individual stages via these tasks, they make a sheet of paper and examine its characters.

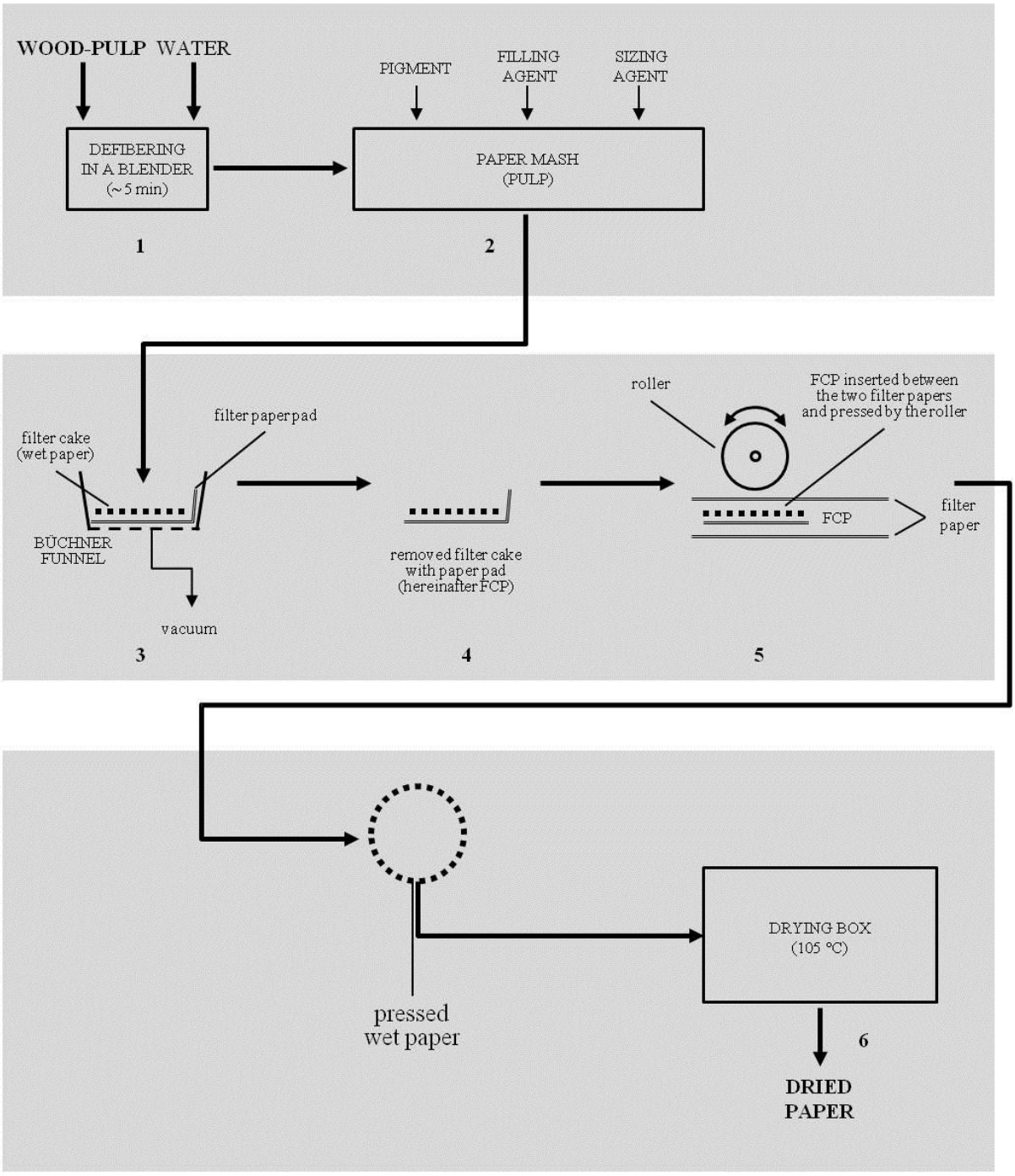


Fig. 5 **Scheme of a demonstration of paper production process**
1-2 pulp preparation
3-5 wet part of paper mill
6 drying part of paper mill

Task no. 1 **Papersheet making** (basic procedure)

Tools:

Pulp (filter paper, sanitary pulp, white "cellulose" toilet paper, Aqua Tube Zewa …), scissors, a beaker (250-400 cm^3), a glass stick, an immersion blender, a Büchner funnel (diameter 9-12,5 cm), a filter flask (500-1000 cm^3), a water pump, a roller.

Procedure:

1. Torn or cut the pulp apart into small pieces, put them into the beaker and pour with water 70-100 cm^3.
2. Take filter paper and cut out a pad for the Büchner funnel according to the given template.
3. Defiber the pulp in the beaker with water by using an immersion blender. Add water to the mash (suspension) to get the final volume of 100-150 cm^3.
4. Put the Büchner funnel with the paper pad on a filter flask. Mix the suspension by a stick and pour it into the Büchner funnel. Shake it to spread the suspension all over the funnel area.
5. Connect a water pump and pump out the water by sequential increasing of the underpressure.
6. Take out the wet sheet of paper together with the pad and insert it between two sheets of filter paper, press it by the roller.
7. Separate the dewatered and pressed sheet of wet paper from the paper pad, place it on a dry paper pad and inside the drying room (with the temperature set up to 105 °C). If you have no drying room available, you can use a heater or let it air-dried till the next day.

Task no. 2 Coloured papersheet making

Tools:

Pulp (filter paper, sanitary pulp, white "cellulose" toilet paper, Aqua Tube Zewa …), pigment/dye (ink, blueberry or raspberry sauce, rose mallow fruit tea …), scissors, a beaker (250-400 cm^3), a glass stick, an immersion blender, a Büchner funnel (diameter 9-12,5 cm), a filter flask (500-1000 cm^3), a water pump, a roller.

Procedure:

1. Torn or cut the pulp apart into small pieces, put them into the beaker and pour with water 70-100 cm^3.

2. Take filter paper and cut out a pad for the Büchner funnel according to the given template.
3. Defiber the pulp in the beaker with water by using an immersion blender.
4. Add pigment/dye to the mash (suspension) according to the deserved shadow and add water to get the final volume of 100-150 cm^3.
5. Put the Büchner funnel with the paper pad on a filter flask. Mix the suspension by a stick and pour it into the Büchner funnel. Shake it to spread the suspension all over the funnel area.
6. Connect a water pump and pump out the water by sequential increasing of the underpressure.
7. Take out the wet sheet of paper together with the pad and insert it between two sheets of filter paper, press it by the roller.
8. Separate the dewatered and pressed sheet of wet paper from the paper pad, place it on a dry paper pad and inside the drying room (with the temperature set up to 105 °C). If you have no drying room available, you can use a heater or let it air-dried till the next day.

Task no. 3 Model of "vat paper" production

Tools:

Pulp (filter paper, sanitary pulp, white "cellulose" toilet paper, Aqua Tube Zewa …), scissors, 2 beakers or any glasses with the volume (250-400 cm^3), 2 beakers or glasses (250-400 cm^3), a tea spoon, plastic or metal tea strainer (diameter 6-8 cm), any heat power (drying place, heater, hot steam oven, hair dryer…).

Procedure:

1. Pick the volume of pulp according to the screen size. The screen with its diameter 6 cm corresponds with about ½ of Aqua Tube roll of the Zewa toilet paper, diameter 8cm with the full roll. If you use any other source materials (sanitary pulp, toilet paper), the teacher will specify the doses.
2. Torn or cut the pulp apart into small pieces, put them into the beaker of 250 cm^3 and pour with water 40-50 $cm^{3.}$ You do not have to torn the Aqua Tube Zewa roll as it will fall apart itself after a while. Use the spoon and mix the mixture. When you use toilet paper, the mixing should be intensive for about 2-3 minutes.
3. Take filter paper and cut out 2-3 round pads for the Büchner funnel according to the given template. The pad size should be equal to the screen diameter.

4. Add water to the mash to get the final volume of 100-150 cm^3, mix again, keep shaking it and pour it over the screen above the larger beaker or glass of about 400 cm^3.
5. Place the screen with pulp over the beaker and leave the mash draining.
6. After a while, place the prepared filter pads on the felted layer of pulp on the screen, press them softly by your hand and remove the pads carefully out of the screen together with the made sheet of paper.
7. Dry everything several times between sheets of filter paper.
8. Finally, separate the newly made sheet of paper from the paper pads and let it dry.
9. You can dry the paper in a drying room or in a hot steam oven (with the temperature set up to 105 °C), on a heater, with a hair dryer or let it air-dried till the next day.

Task no.4 Model of coloured "vat paper" production

Tools:

Pulp (sanitary pulp, white "cellulose" toilet paper, Aqua Tube Zewa …), pigment/dye (ink, blueberry or raspberry sauce, rose mallow fruit tea …), scissors, 2 beakers or glasses (250-400 cm^3), a tea spoon, filter paper, plastic or metal tea strainer (diameter 6-8 cm), any heat power (drying place, heater, hot steam oven, hair dryer…).

Procedure:

1. Pick the volume of pulp according to the screen size. The screen with its diameter 6 cm corresponds with about ½ of Aqua Tube roll of the Zewa toilet paper, diameter 8cm with the full roll. If you use any other source materials (sanitary pulp, toilet paper), the teacher will specify the doses.
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7. Dry everything several times between sheets of filter paper.
8. Finally, separate the newly made sheet of paper from the paper pads and let it dry.
9. You can dry the paper in a drying room or in a hot steam oven (with the temperature set up to 105 °C), on a heater, with a hair dryer or let it air-dried till the next day.

Task no.5 Evaluation of paper characters

Tasks: a) Compare the sized and non-sized paper.
b) Examine, how adhesive is the pigment on the papersheet.

Tools:

Paper samples made in the previous tasks, a sheet of writing paper, blue ink, redipen (top point diameter 0,5-2 mm), a pen holder, a beaker (250-400 cm^3), filter paper.

Procedure:

a) Comparison of sized and non-sized paper

It is simple to find the difference between sized and non-sized paper. Use a redipen, wet it with blue ink and write several collinear and crosswise lines on a sample of the sized paper. Then repeat the procedure on a sample of non-sized paper. Compare both of the samples.

b) Pigment adhesion on paper

Take a sample of drought coloured paper and put it into water for a moment, pull it out and place it on clean filter paper. How much did the pigment infuse into the water? Was there any colour mark remaining on the white filter paper?

Optional tasks

Task no.6 Papersheet size determination

There are different sizes of papersheets which determine the paper **format**. These are marked by a capital letter and a number, e.g. A4, A5, B2, C2. The basic format sizes are A, where the lengths of paper sides are in proportion $1:\sqrt{2}$. The basic format is A0, its surface area is 1 m^2. The format A1 and any other following ones are formed by making halves of the longer side of the sheet, see the fig. 6. The side lengths are rounded to millimeters.

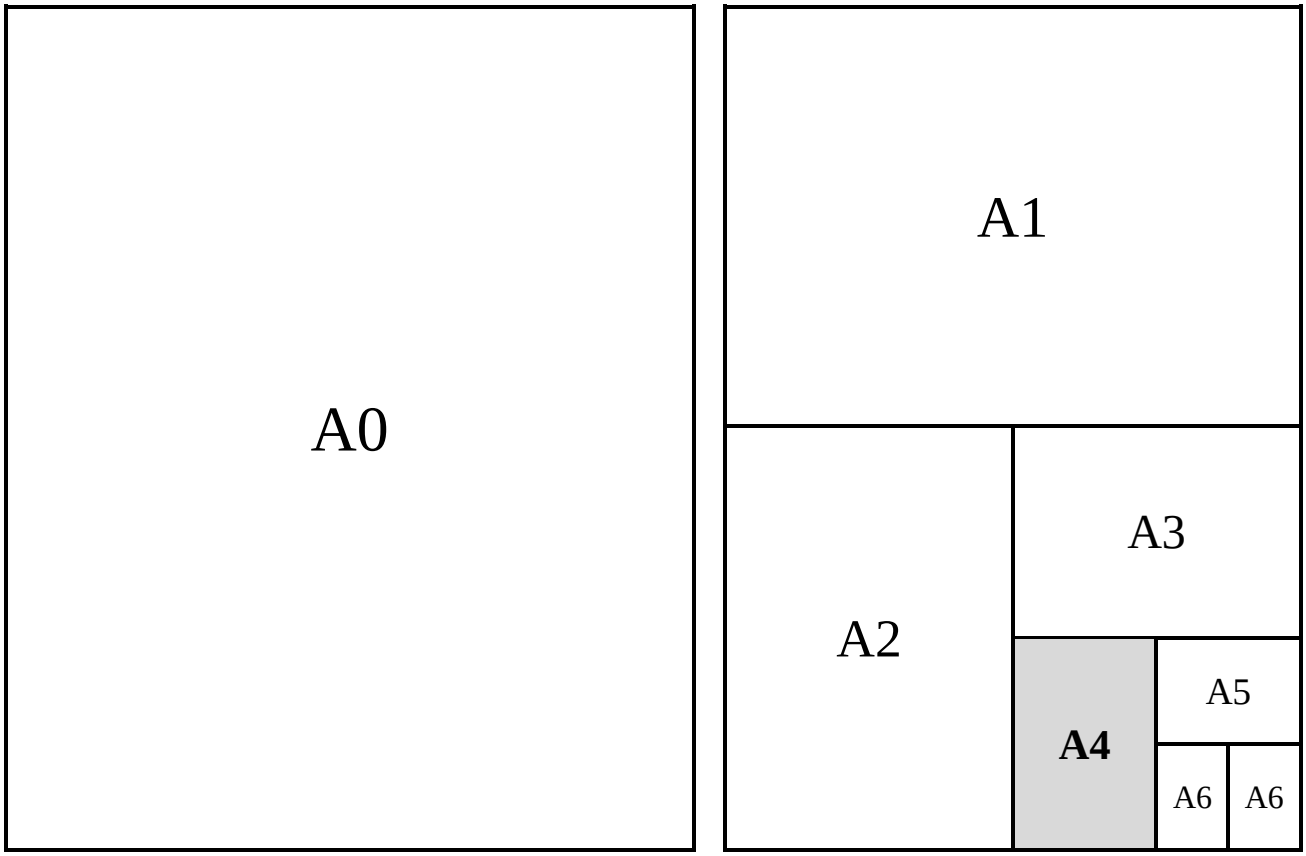

Fig. 6 **Paper format** – size A

Task:

Measure the lengths of a sheet of A4 paper, count the sizes of other formats and fill them into the fig. 6 *(sizes are indicated in mm).*

Task no.7 Paper area weight determination

Except from various sizes, a papersheet can have a different thickness too. Individual types state the paper **weight in grams** or **grammage,** which defines the weight of 1 m^2 of paper. The higher weight in grams, the thicker sheet of paper.

Task:

Prepare various paper samples - printing paper, drawing paper, cardboard and so on. Measure the sizes per each sample and calculate its surface area. Then weigh the sample and calculate its surface weight (*indicated in v* g/m^2*).* Write the data you obtain down into the following table:

Type of paper	Dimension [cm x cm]	Surface area [cm^2]	[m^2]	Weight [g]	**Grammage [g/m^2]**
printing paper					
drawing paper					

Task no.8 Project on the topic „PAPER“

Search for available information about paper production process, types of paper and its use in daily life in literature or internet. Arrange the gained data, illustrate the text with pictures and samples of various paper products. Make the project in the form of poster (*drawing paper size A3 or larger).*