**Measuring Swelling Along Two Paper Directions**

Base your answers on the information provided and your knowledge of chemistry. Use the 2025 Chemistry Reference Tables as needed.

An exhibit team attaches paper panels to rigid frames. Its classroom model treats a panel as many cellulose fibers aligned mostly along one direction. Water can associate with groups on the fibers. When the paper absorbs moisture, the model fibers swell more across their width than along their length.

| Panel direction | Length when dry (mm) | Length after humid exposure (mm) |
|---|---|---|
| Along the fibers | 100.0 | 100.4 |
| Across the fibers | 100.0 | 102.2 |

**1** Calculate how much more the panel expanded across the fibers than along them. Show how the four readings enter the calculation. [1]

Answer and work

**2** Use the fiber model to explain why equal starting lengths do not expand by equal amounts. [1]

Answer and work

The frame holds the left edge fixed. The team can turn the paper by 90° before attaching it. The right edge has 1.0 mm of room for expansion.

**3** Which direction should run horizontally toward that edge under the measured conditions?

(1) Along the fibers only

(2) Across the fibers only

(3) Either direction fits the available room.

(4) Neither direction fits the available room.

**4** A second panel has fibers arranged in many directions. Explain what the team should measure to find out whether its expansion still depends on direction. [1]

Answer and work