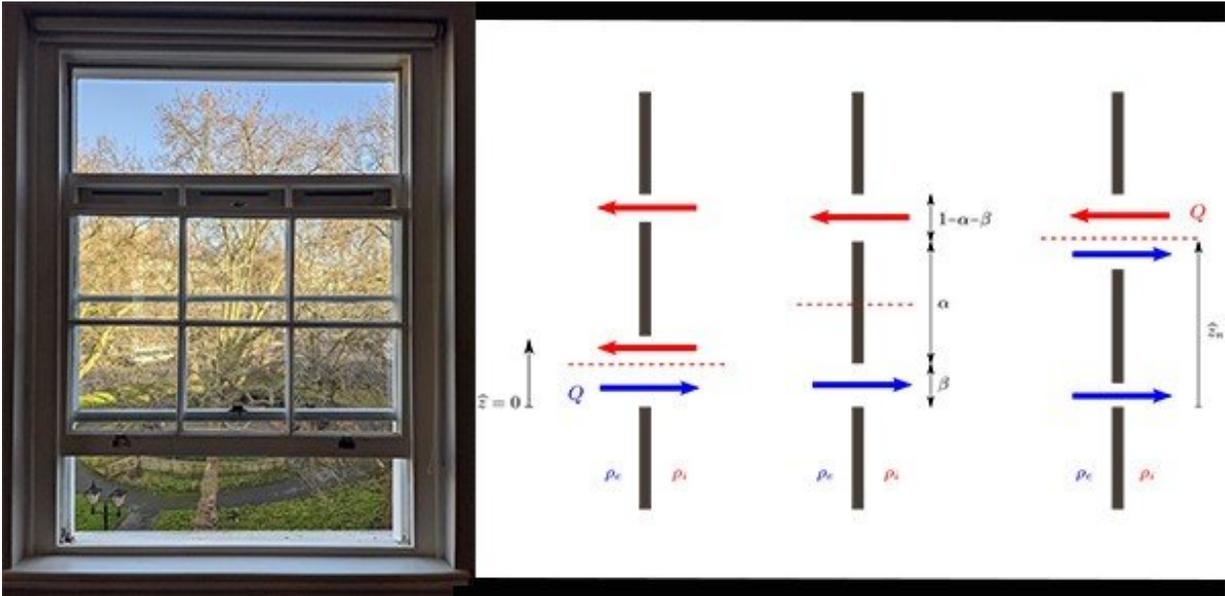


The science behind sash windows and how they ventilate our homes

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Three different flow regimes through a sash window, as identified by the researchers, from left: bidirectional flow at the lower opening; unidirectional flow; bidirectional flow at the upper opening. Credit: University of Cambridge

Researchers have assessed the natural ventilation flow rate through a sash window—a common feature in domestic buildings—to inform smart and low energy building design.

Effective ventilation not only improves [indoor air quality](#), but it can also limit the risk of transmission of airborne infections by circulating fresh

air in the room. In order to implement any ventilation strategy, a good understanding of the flow physics is required, along with simple and accurate models that can be easily implemented to help optimize the performance of new and existing buildings.

A traditional sash window has two vertical sliding panes that allow the window to be open at the top and/or bottom. Using simple models to estimate the ventilation through the window, the researchers, led by the University of Cambridge, examine buoyancy-driven ventilation of a closed room with one open sash window, where the indoor temperature is warmer than outdoors.

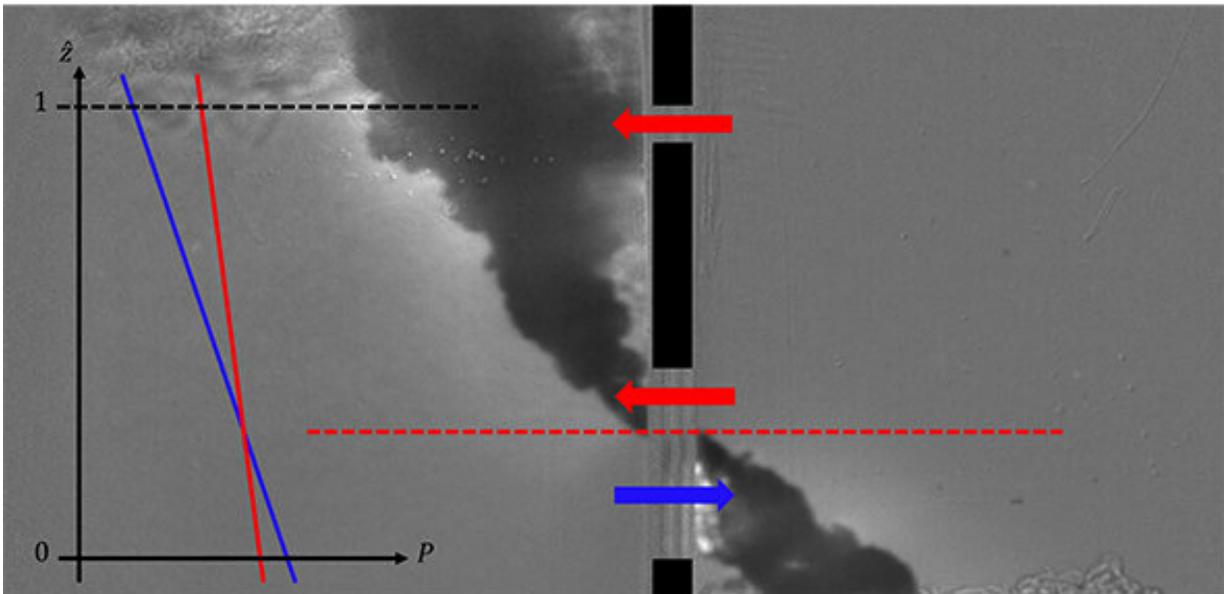
In winter, buoyancy-driven ventilation—which relies on the temperature difference of lighter warm air inside the building and heavier colder air outside the building—uses the heat indoors (generated by our bodies and appliances) to drive a flow and ventilate a building. For example, when a sash window is open, the lighter air will escape through the top and the colder air will enter the building through the bottom.

The researchers identified three different flow regimes that may occur: bidirectional flow through the lower window, unidirectional flow through each opening and bidirectional flow through the upper window—thus leading to different flow rates. Their results are reported in the journal *Flow*. The model they have developed is applicable to any sash window and estimates the flow regime that is occurring, as well as the ventilation flow rate from the sash window configuration and the temperature difference.

Calculating ventilation flow rates (the volume of air that is provided to a room over a period of time) is important in order to model indoor air quality, which is often done in the pre-construction or retrofit evaluation of building design. These calculations can be used to determine the energy impact of ventilation and to estimate the transfer of airborne

pollutants, for example, resulting in models which can be integrated into programs controlling the ventilation of smart buildings.

The different flow regimes, identified by the researchers, were tested with small-scale experiments using a tank filled with fresh and salt water compartments, separated by a barrier with an opening in it to represent a full-scale sash window. The experiment was backlit with a projector using a 45-degree mirror, with the light passing through the experiment projected onto a sheet of tracing paper—a technique known as shadowgraph—and used for flow visualization.



Shadowgraph of a water tank experiment, where a bidirectional flow along the lower opening of the sash window can be observed. Credit: University of Cambridge

The researchers show that for a given closed height of the sash window, the maximum ventilation rate is obtained for a symmetric sash window

configuration—when the heights of the lower and upper openings are the same. They show that as the size of the closed panel relative to the total window area increases, the ventilation rate becomes more sensitive to the geometry of the openings. When the height of the closed part of the sash window represents 50% of the total height, the maximum ventilation flow rate is almost double that of the minimum flow rate. Meanwhile, when 90% of the sash window is closed, the maximum ventilation flow rate is more than four times larger than the minimum flow rate.

Gaël Kemp, Ph.D. student and co-author of the paper, said: "The primary purpose of ventilation is the removal of pollutants and heat. If used correctly, sash windows can be very effective sources of ventilation. Using a semi-analytic and analytic modeling approach, tested with small-scale lab experiments, we assess the optimal sash [window](#) arrangement for different natural ventilation strategies. Our results can be used in smart buildings to open automatically sash windows to obtain the desired flow regime and [ventilation](#) rate."

More information: Gaël F. Kemp et al, Fluid mechanics of sash windows, *Flow* (2022). [DOI: 10.1017/flo.2021.14](https://doi.org/10.1017/flo.2021.14)

Provided by University of Cambridge

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