Modelling Workshop MISGSA 2021: Covid-19 Masks

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Masks

The aim is to determine design principles for masks in a Covid-19 context for the wearer and victim; we want the best mask consistent with personal comfort.
Note:

- In the absence of masks large and intermediate size droplets (5 μm $\rightarrow$ 1 mm) travel a distance of the order of 90 cm. Aerosols travel further and remain longer. Which matter most?
- Evidently an impermeable mask exactly fitting onto the individual's face will prevent the spread the virus but will kill the wearer. Also we know a comfortable but very crude and poorly fitting mask will be useless.
- Even with specially designed well fitted masks (N95) significant leakage and through-flow occurs. Wearers of N95 can have difficulty breathing.

Flow Behaviour

Question 1: What permeability (fabric thickness and weave) and fitting parameters (size, shape) will be 'best'?
Observations:

- The air stream and will either pass through the mask or leak out of the mask.
- The volume of space between the mask and face must be sufficient and/or the mask flexible enough to allow for comfortable air exchange due to breathing.

A 'More Refined' Question: If δ is the average thickness of the gap around the mask edge (length L, area A), and k is the permeability (so that flux/area $q = -kp_x$), determine the (leakage flux)/(mask through flux) ratio as a function of relevant parameters under sneeze, cough or normal conditions.

Droplets/Sneezing

A sneeze or cough consists of a jet of air carrying droplets:

- The droplets (containing the virus) are carried in the air stream and will either be absorbed in the mask fabric or be expelled through or around the mask.
- The air stream spreads out with distance with the velocity decreasing, so droplet concentration levels drop.
  Question 2: (with the sneeze group) How does the sectional area of the jet vary with distance from the source, and what droplet concentration levels will result with and without the mask?
- Droplets will carry from the source (an infected person) to a sink (another person or surface). What size droplets are produced in a sneeze? How far? What size distribution, and what matters from the virus spread point of view (aerosols, larger droplets...)?
  These are issues we may look at in concert with our sneeze colleagues.

References: see

We need to get up to speed. Here are some excellent references.

(1) Dbouk T, Drikakis D. On respiratory droplets and face masks. Physics of Fluids. 2020;32(6). doi.org/10.1063/5.0015044 (https://aip.scitation.org/doi/10.1063/5.0015044)

(2) Cummings C. P. Ajayi O. J., Mehendale F. M., Gabi R., Viola I. M. The dispersal of spherical droplets in source-sink flows and their relevance in the Covid-19 pandemic. Physics of Fluids 32, 083302 (2020).

(3) Wang B., Wu H., Wan X. Transport and fate of human droplets- A modelling approach. Physics of Fluids 32, 083307 (2020).

These references (and others) can be found in Problem 3 supporting material in MISG Problems. See especially'⋆⋆ Covid-19 Protection Methods' for modelling thoughts.

Objectives

This is both an interesting and important problem with many issues. There are no experts here. We want to set ourselves up for the followup MISG work:

- Primary aim:To understand what is known; The above references are excellent and provide an overview of possible approaches.
- Report: In your presentation/report should present a summary of the above material and provide useful data for the MISG.
- Report: Also I would like you to set up some models for the questions above; for suggestions, see $\star\star$ above. This work should be also in the report/presentation.

Technical background: there is work for all.