Solved: the mystery of why it's impossible to pull apart interleaved phone books

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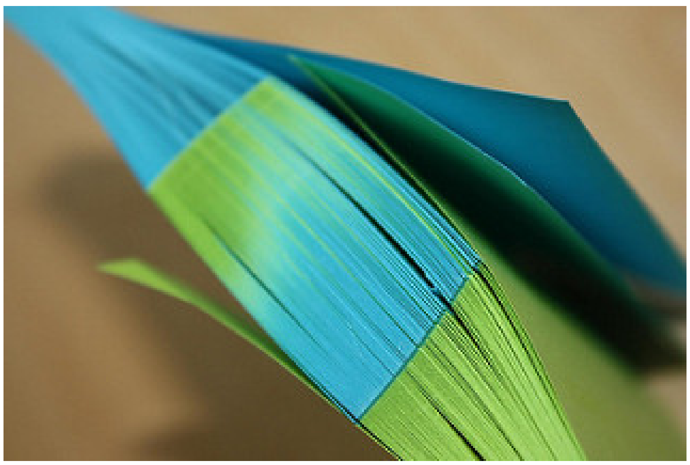

No glue, only friction. Credit: Danny Nicholson/Flickr, CC BY-NC-ND

People, trucks and even military tanks have tried and failed the task of pulling apart two phone books lying face up with their pages interleaved, like a shuffled deck of cards. While physicists have long known that this must be due to enormous frictional forces, exactly how these forces are generated has been an enigma – until now.

A team of physicists from France and Canada has discovered that it is the layout of the books coupled with the act of pulling that is producing the force.

The power of approximation

Finding an approximate solution to a complex problem is an essential skill in science (and in life). Often we are faced with questions that we can't answer exactly, but sometimes good enough is, well, good enough. Enrico Fermi, one of the greatest physicists in the 20th century, has given his name to such "Fermi Questions" – as he was famous for encouraging this skill in his students.

Here's one example: "How many piano tuners are there in Chicago?". I have no idea, and I'm not sure Fermi knew either. But by estimating the population of Chicago, the fraction that might play the piano, and how often a piano needs tuning, you can come up with a pretty good guess, without diving into the phone book (it's probably closer to 100 than to 1,000).

Doing these "back-of-an-envelope" calculations is usually the first step in approaching a scientific question. Sometimes that is as far as you need to go. Sometimes it tells us that the question is worth investigating more to find the exact answer.

This is exactly what the team investigating the friction of phone books did. The back-of-the-envelope answer is friction between the pages. However, assuming the friction is proportional to the number of pages drastically underestimates the total force that is generated (which seems to rise exponentially with the number of pages). But previous attempts to improve this simple model – by including the effects of gravity and air pressure pushing the pages of the books together – have all failed to explain the result.

Surprisingly simple

So, when the back-of-the-envelope calculation fails, things get serious. In this case, the traction instrument was brought out (think the opposite of a vice), it was used to pull books apart while measuring the force required to do so. But not just any books. Rigorously prepared test books with specific numbers of pages, built from paper sheets of exact dimensions, interleaved to high precision.

Data in hand, a mathematical model was put together, and it turned out to be driven by a surprisingly simple fact. The pages of each book are separated by the interleaving and end up "spreading out", lying at a slight angle from the spine. When the books are pulled away from each other, the pages want to move back closer together and end up squeezing the interleaved pages from the other book. And gripping something tightly greatly increases the friction.

As an example, imagine a person with long hair in a swimming pool. While floating underwater, their hair can spread out – much like the pages of the books are spread out by the interleaving. Then, if our volunteer swims off, their hair will naturally move close together, following their head which is pulling it along. The pages of our books also want to move close together behind the thing pulling them (the spine of the book), but instead just squeeze more tightly on the pages of the other book, which are in the way. Pulling harder on the books only increases the friction.

This is an example of the geometrical amplification of friction, or how the layout of the books produces forces far beyond what is expected. Knots are another example, looping a rope around itself greatly increases the friction, resulting in a secure grip. The authors point out the recent resurgence of interest in this kind of problem and the general field of tribology, the study of surfaces in relative motion.

This is being driven by the need to understand the structure and behaviour of new micro and nano-engineered materials, which have impact on many aspects of life from medical applications to solar cells.

Interleaved carbon nano-tubes as the material of the future anyone?

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