

Spring cleaning

What prompts us to clean in spring?

Why not Summer or Autumn? It's not like making pancakes, when one day is in the calendar, liked to our main religious seasons. Nor like bank holidays set by statute. It is also surprisingly universal around the world and across cultures and around the world. So with no rules or calendar to guide us, what induces us to choose the spring season to have a good clean up?

Dr Hadley's rate of change hypothesis

The inclination to spring clean can't be due to the amount of daylight as some people suggest or we would do more cleaning in the summer when the days are longest, and would be much later in Northern latitudes. The distinguishing aspect of spring is that the rate of change of daylight hours is highest, this peaks at the spring equinox (** check**) and roughly follows a sinusoidal curve which is high (90%) *** days either side of it.

Our inclination to spring clean is related to the rate at which days get longer. The time of year when change is greatest.

The length of the day and the rate it changes are a complex interaction between the rotation of the Earth around the sun while it spins each day about a different axis – and at the same time moves slightly closer and further from the sun (closest in winter strangely). We have known these equations accurately for a long time, they were needed to design sundials and to navigate ships using compass and sextant. NOAA (The National Oceanic and Atmospheric Administration) gives a spreadsheet with 30 columns that calculates sun rise and sunset times. The length of a day is given approximately by:

$$D = 8 \cos^{-1} \left\{ \left(\frac{\cos(90.833)}{\cos(\phi)} \right) \cos(\delta) - \tan \delta \tan \phi \right\}$$

Where ϕ is the latitude and δ is the declination of the sun. Simple? Well to use it we need to know the declination of the sun on any particular day. That is more complicated. A very simple version is:

$$\delta = -23.44^\circ \cos\left(\frac{360}{365} \cdot (N + 10)\right)$$

Where N is the number of days since Jan 1st. The 23.44° is the angle the Earth is tilted at – just like you see for most globes. To be more accurate you need to compensate for the Earth's orbit being elliptical rather than circular.

You can find the fastest change by plotting out the functions or differentiating them. The change is greatest on 18 March (which is two days before the spring equinox on 20 March 2013). The rate of change about half an hour each week for an extended period, one month either side 18 March.

Added to the natural change of 30 minutes a week, we see a further one hour of change on 31st March when British Summer time starts.

Optimal vacuum cleaning

We have all used a vacuum cleaner, but a bit of physics explains how to optimise the techniques.

The optimal hovering angle

For Comfort

The effort to hold the Hoover increases as the tube gets closer to horizontal.

$$W = \frac{Mg}{2} \cos(\theta)$$

Where W is the force needed to hold the handle in place, M is the mass of the vacuum cleaner tube, g the gravitational constant and θ is the angle to the horizontal.

For efficiency

So it is easier to hold it upright but when you need to push it forward the picture changes, because when you move it, you press down and push forwards at the same time. The force required to push forward increases as it becomes more vertical:

$$T = \sin\left(\theta + \frac{\tan^{-1}\left(\frac{1}{\mu}\right)}{\sqrt{1 - \mu^2}}\right)$$

Where T is the force pushing the vacuum cleaner along and μ is the friction coefficient with the floor or carpet. This gets easier as the angle drops closer to horizontal. At 45° you are putting in as much effort going forward as pushing down. You will need to go steeper than that if you want to push down hard for a scrubbing action.

How fast can you Hoover

As the Hoover passes over the dirt the air flow needs to accelerate the dust and bring it into the airflow and then you need to allow enough time for the dust to be drawn into the cleaner head before it passes on.

Acceleration

$$m a = 6 \pi \eta r v - 2 P_A \pi r^2$$

This is an application of Stokes' law. The acceleration of the dust particle is a . η is the viscosity of air, r and m are the radius and mass of a dust particle and v is the speed of air due to the vacuum cleaner. P_A is the adhesive suction holding the dust in place. If the particle is loose, then P_A is zero, and the acceleration is faster than a grand prix car. If P_A is too large the dust or dirt won't move.

Speed of vacuuming

Once the dust is caught up in the flow of air from the vacuum cleaner, then it needs to travel into the tube before you Hoover past it. That allows you to Hoover at 10metres per second (20 miles per hour) and still collect all the loose dust.

Dusting

Dusting physically picks up the dust in a cloth. The cloth is smaller than a vacuum cleaner head and does not move so fast: vacuuming floors is faster than dusting! Dust particles are very small and light but with a relatively high surface area, (They would have an incredibly small body mass index!). As with vacuuming, the cleaning force F_c has to be greater than the Adhesive force acting on the surface area of the dust.

$$F_c > 2 P_A \pi r^2$$

Conclusion

It's all about adhesion, your cleaning forces have to overcome adhesion. That is where elbow grease and cleaning chemicals come in - scrubbing applies more force, while chemicals can dramatically reduce P_A . If there is one equation that sums it up, then it is:

$$6 \pi \eta r v > 2 P_A \pi r^2$$

Which says that the cleaning forces from any type of suction has to exceed the stickiness of the dirt.

For completeness: η is the viscosity of air, r is the radius of a dust particle and v is the speed of air due to the vacuum cleaner. P_A is the adhesive suction holding the dust in place

We can rearrange the equation to make it even clearer what we have to do for a clean house:

$$\frac{3\eta v}{r} > P_A$$

This applies whenever we are trying to suck or wash dirt away. It shows straight away that small particles are easier to dislodge. After that the lefthand side tells us:

- η is the viscosity that goes up dramatically (200 x) if we use water instead of air.
- v is the velocity of the fluid, for stubborn dirt you can turn the vacuum up to max, or use a small nozzle, or for water use a power wash.

And after that we need to tackle the RHS: P_A is the stickiness of the dirt. Obviously, we need to reduce it:

- Use water: it is a solvent it does not give more cleaning force, it also weakens the bonds sticking the dirt to your surfaces.
- Use a solvent of some sort, though that depends critically on all the materials.
- Use a detergent, these generally reduce adhesion on all sorts of materials.