Towards a Practical Philosophy of Science
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session: Practices of Measuring, Experimenting, and Theorizing

Measurement and the revised SI: between theory and practice

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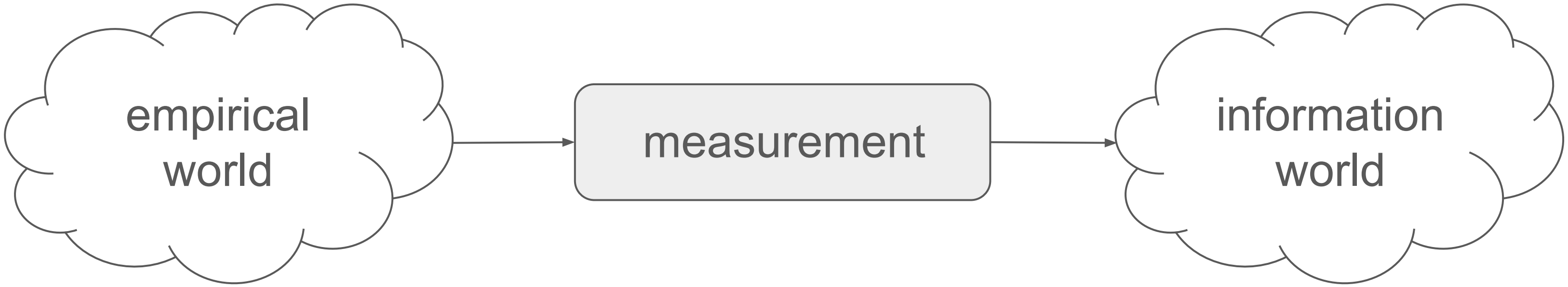
My position (*a proposal for discussion*)

Measurement is an empirical and informational process
that is designed on purpose,
whose input is an empirical property of an object,
and that produces both information in the form of values of that property
and meta-information about the explicit justification of this information



The bridge between the two worlds is realized by scales, and then units

An example: what is the metre?

Principled answer:
– it is a length l^* of something (hence an empirical entity)
– to which the numerical value 1 (an information entity) is attributed
(so that, by definition, the value of the metre is $1\ \mathrm{m}$: $l^* = 1\ \mathrm{m}$ – the bridge!)

Consequence:
– if an object a has a length l_a that is twice the metre, $l_\mathrm{a} = 2\, l^*$ (an empirical relation)
then the value of its length is $2\ \mathrm{m}$: $l_\mathrm{a} = 2\ \mathrm{m}$

Consequence:
– if the something whose length we identified as the metre changed its length,
then $l_\mathrm{a} = 2\ \mathrm{m}$ would be false even though l_a (and this for any a!)

The stability of units is a very critical requirement

An example: what is the metre?

The history of the answers to this questions can be understood as a sequence of steps toward a more and more stable l^*

Step 1. The length of a given object s, l_s, is chosen and defined as the unit l^* :

$$l^*_{\text{step1}} := l_s$$

This was the strategy adopted in the 1875 definition of the metre, as the length of the international prototype of platinum-iridium

An example: what is the metre?

Step 2. The 1960 definition of the metre has a slightly different formal structure:

$$l^*_{\text{step2}} := k\, l_{\text{s}}$$

where l_{s} is not the length of a given object but the length of a given phenomenon (the wavelength of the radiation corresponding to a given transition in krypton 86), and k is a numerical factor chosen for guaranteeing that $l^*_{\text{step2}} = l^*_{\text{step1}}$,
i.e., that the length identified as the metre remains the same

(The 1960 definition: “The metre is the length equal to 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels 2p10 and 5d5 of the krypton 86 atom.”)

An example: what is the metre?

Step 3. Like in Step 2, the 1983 definition is based on an assumed constant quantity of a given phenomenon (the speed of light in vacuum), but now the defining constant is not a length but a velocity, thus under the assumption of a nomological relation between length, L, velocity, V, and time duration T, where then $L = f(V, T) = V\,T$:

$$l^*_{\mathrm{step3}} := k\,f(v_{\mathrm{s1}}, t_{\mathrm{s2}})$$

where v_{s1} is the speed of light in vacuum and t_{s2} is the time identified as the second Again, k is a numerical factor, chosen for guaranteeing that $l^*_{\mathrm{step3}} = l^*_{\mathrm{step2}}$

(The 1983 definition: “The metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.”)

An example: what is the metre?

Step 4. The 2019 definition of the metre has the same empirical content and nomological assumptions as the 1983 definition, but with a different formal structure

Given the relation $V = f(L, T) = L\,/\,T$, a speed v_{s1} (the speed of light in vacuum), a time t_{s2} (the second), and a numerical constant k (299 792 458) are chosen, such that the numerical value of v_{s1} is k when expressed in the unit $\mathrm{m\,s^{-1}}$

Hence $v_{s1} = k\,\mathrm{m\,s^{-1}}$, and therefore

$$l^*_{\text{step4}} := v_{s1}\, t_{s2}\,/\,k$$

where v_{s1} is the "defining constant" and k is chosen for guaranteeing that $l^*_{\text{step4}} = l^*_{\text{step3}}$

(The 2019 definition: "The metre, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum, *c*, to be 299 792 458 when expressed in the unit m

As a summary: the stability of the bridge relies on…

Step 1 (unit as property of an object):
… the stability, including appropriate maintenance, etc., of the chosen object

Step 2 (unit as property of a phenomenon):
… the stability of the chosen phenomenon

Step 3 (unit as property of a phenomenon of a different kind):
… the stability of the chosen phenomenon as measured
and the correctness of the nomological relation among the involved quantities

Step 4 (unit as property of a phenomenon of a different kind):
… the stability of the chosen phenomenon as defined
and the correctness of the nomological relation among the involved quantities

One more thing…

Since Step 2, in principle everyone who can realize the chosen phenomenon can also produce an artifact embodying the unit, i.e., a measurement standard

But the greater is the expected stability,
the harder is the production of primary measurement standards:

for practical, if not political anymore, reasons,
the metrological system still maintains its purpose

Thank you for your attention

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