Measurement Standards Laboratory of New Zealand

What is the M-layer aspect?

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Outline

- What is an M-layer (service) for?
  - Different ways of expressing data
  - Semantic interoperability for producers and consumers
  - Disambiguating alternative expressions
- M-layer ***aspect*** vs physical ***quantity kind***, what is the difference?
- Final comments

Quantity—an amount of something, but what?

"It's hot today, 30 degrees"

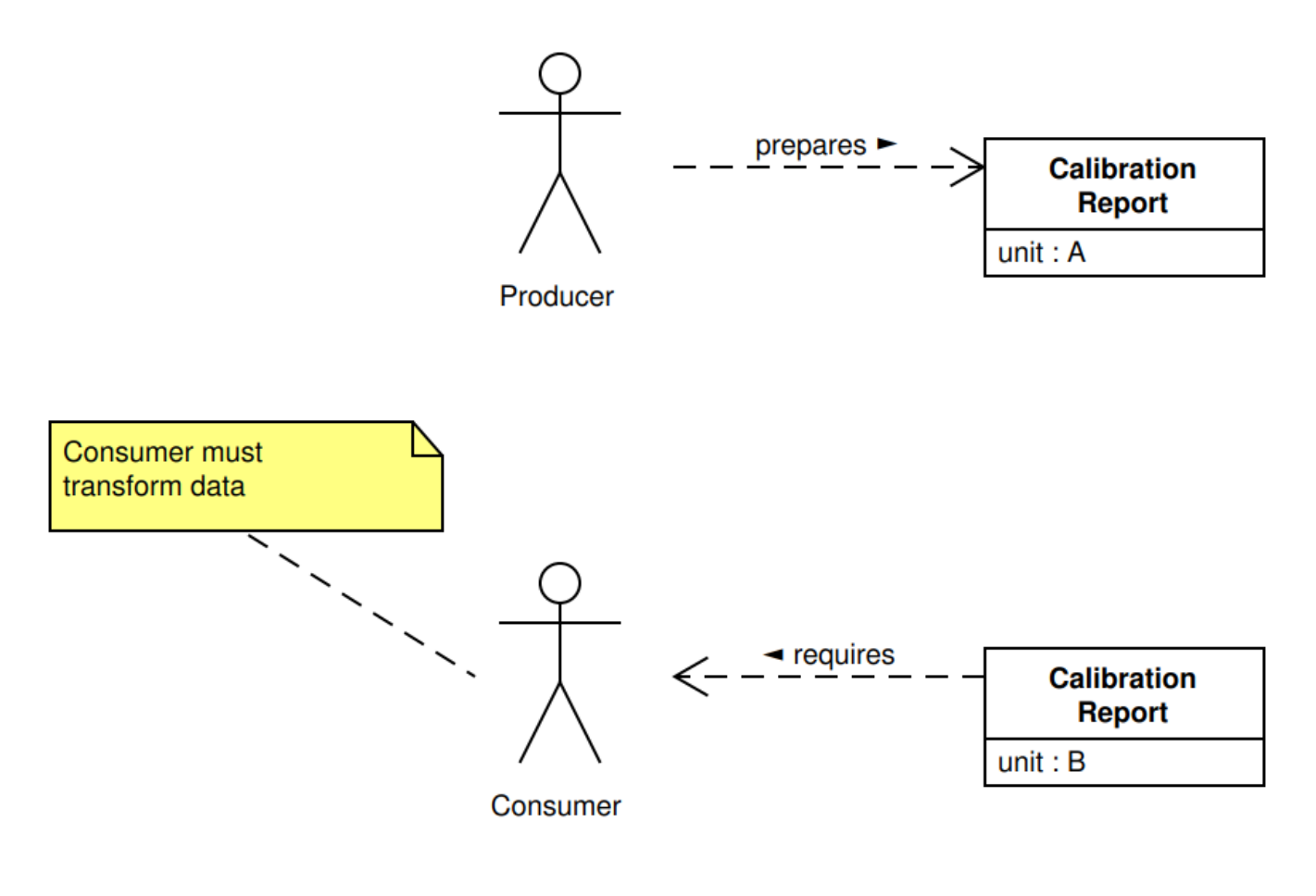
"Really!? It feels more like 90!"

Conventional units of temperature are different in the United States (degrees Fahrenheit) and Europe (degrees Celsius).

People get used to it!

Digital systems must deal with these conventions. Just as with regional differences in languages, currencies, time-of-day formats, etc.

Producers and consumers of data

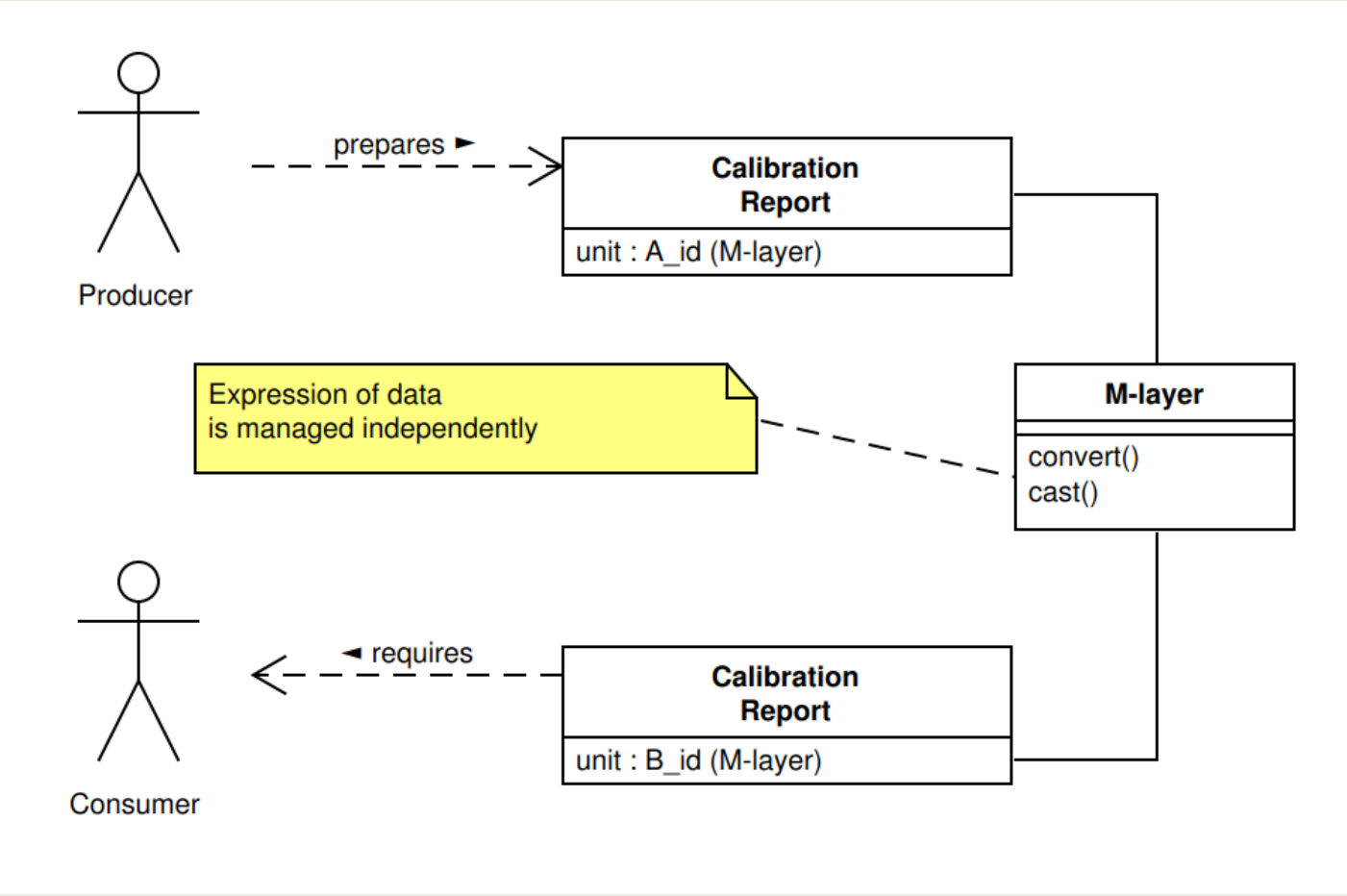


A producer cannot know the requirements of (possibly many) consumers of data

Consumers have the job of transforming the data

Repetitive work, and subject to error

Producers and consumers need help—interoperability



The form of expression is identified clearly

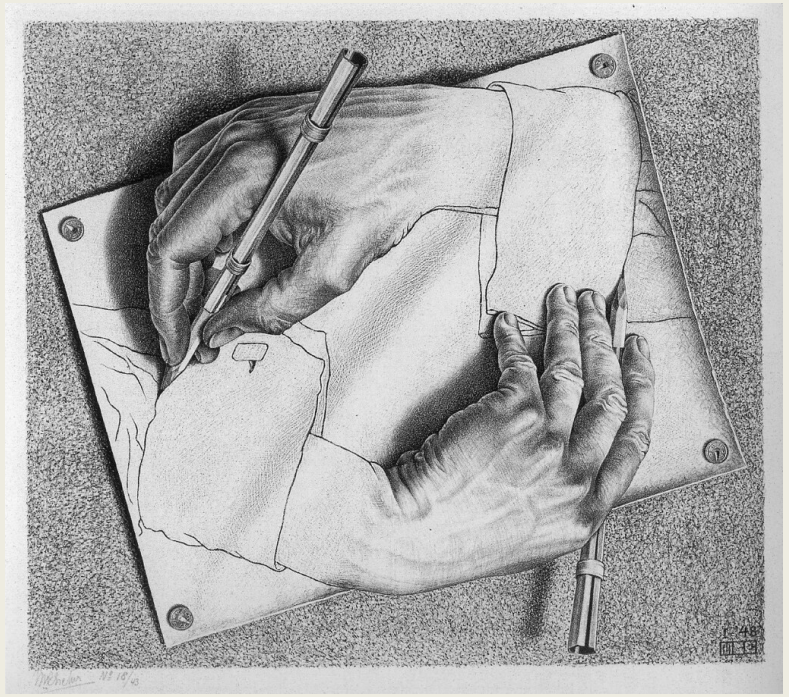
Alternative legitimate forms of expression are centrally managed

The data may be expressed according to consumer needs

"The next 700 unit-measurement checkers" [1]

"Insanity is doing the same thing over and over and expecting different results."

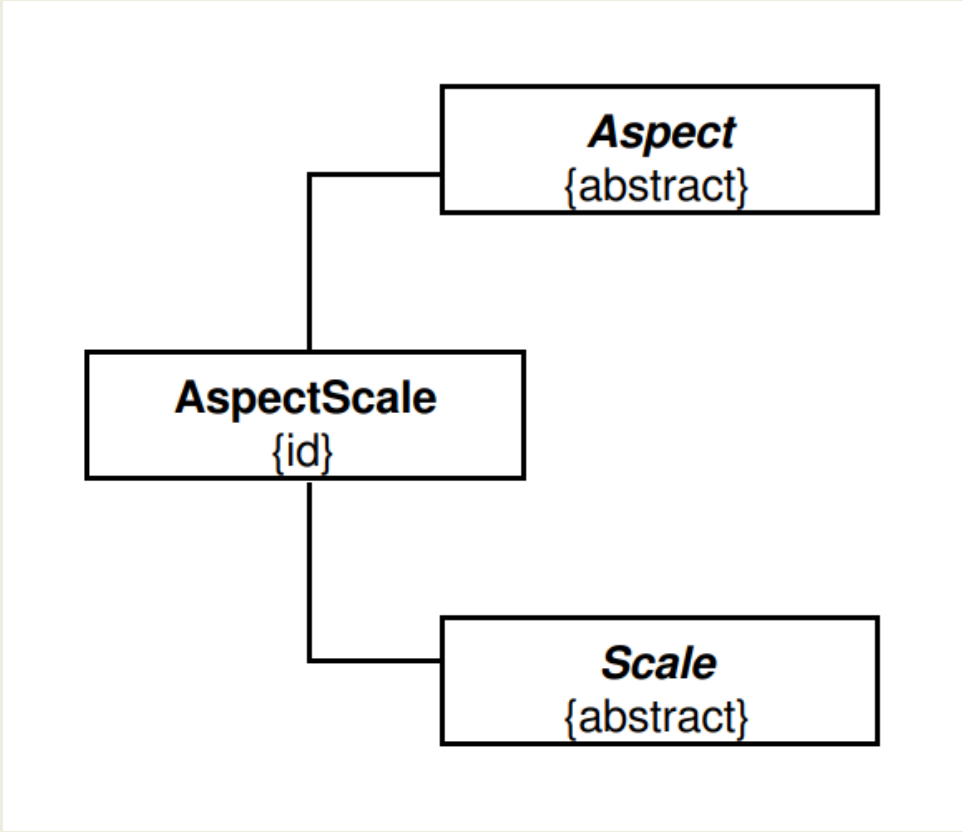
The M-layer is a conceptual model for digital systems to unambiguously represent alternative forms of expression for physical data



M. C. Escher, Drawing Hands, 1948

[1] O. Bennich-Bjoerkman and S McKeever, DOI 10.1145/3276604.3276613

M-layer has identifier pairs



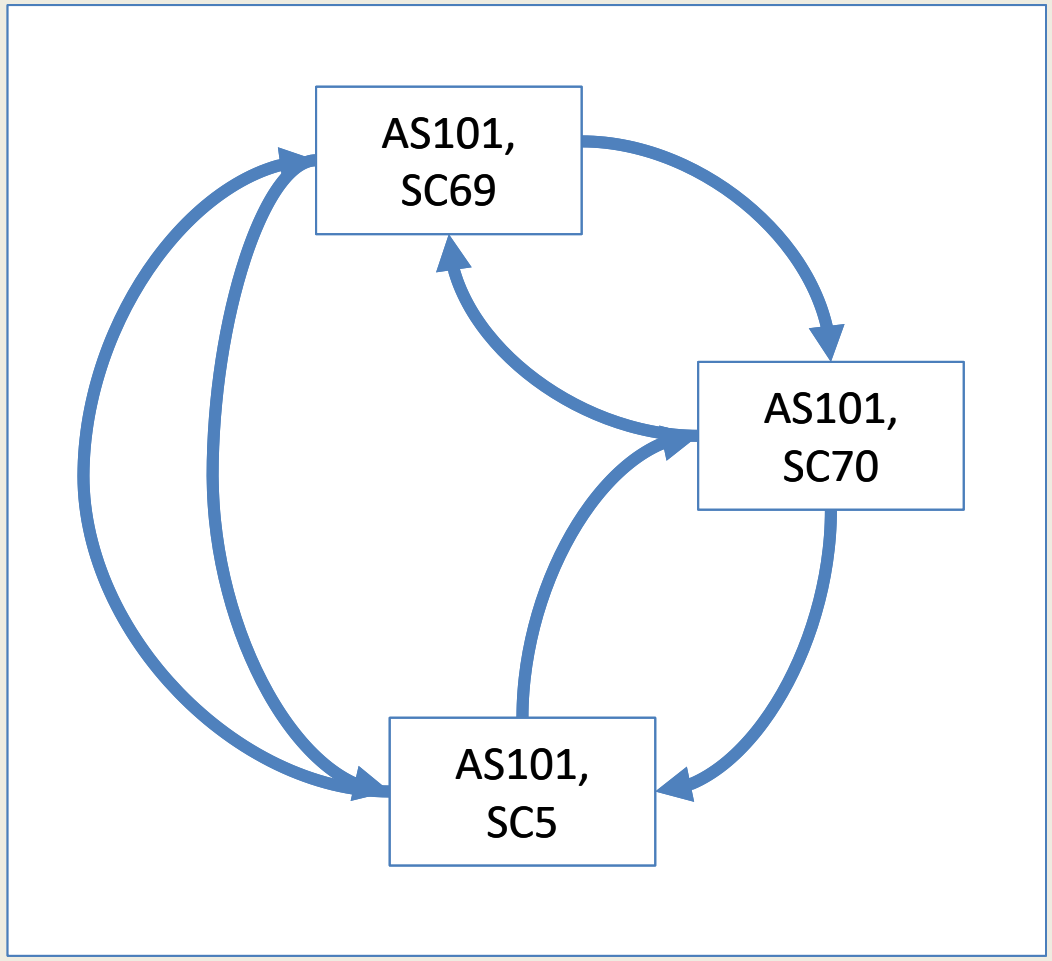
Aspect is like a quantity kind, such as mass, length, speed.

Scale is like a unit, such as kg, m, m/s.

But aspect and scale are not really quantity kinds and units, respectively.

The M-layer aspect and scale identifiers **unambiguously label alternative forms of expression.**

The M-layer maps alternative expressions



AS101 ⇔ thermodynamic temperature
SC69 ⇔ °C; SC70 ⇔ °F; SC5 ⇔ K

The M-layer holds relationships among alternative forms of expression

Nodes represent forms of expression

Edges represent transformation from one form to another

A URI prefix renders these short identifiers unique, e.g.:
https://mlayer.org/AS101

Forms of expression must consider data sets

Metrological data always has a range (e.g., a data set)

Some properties remain invariant under certain types of transformation

The M-layer distinguishes between transformations that leave properties of data invariant, and other transforms

Together, aspect and scale identifier pairs label each form of expression

Temp: {15 °C, 25 °C, 30 °C}

Temp: {59.0 °F, 77.0 °F, 86.0 °F}

Means (sample): 23.33 °C and 74.0 °F

Direct transform: 23.33 °C ⇔ 74.0 °F

Ratio (max/min): 2.0 ≠ 1.46

The SI and quantity kinds

Some unit symbols in the SI are products of powers of base units

Units in this class are sufficient to express any SI quantity

However, the quantity kind is not indicated

Units are not unique identifiers of quantity

This confuses many people, so it will probably confuse machines too.

$$\mathrm{s}^{-1}$$

$$\mathrm{m}^2 \cdot \mathrm{s}^{-2}$$

$$\mathrm{kg} \cdot \mathrm{m}^2 \cdot \mathrm{s}^{-2}$$

The SI special unit names and quantity kinds

There are 22 units with special names in the SI

Used in isolation, the expressed quantity kind is indicated

Used in products of powers, ambiguity is still possible

Quantity kind (for aspect) is needed to identify legitimate transformations

$$\begin{aligned} \mathrm{Hz},\ \mathrm{Bq},\ (\mathrm{s}^{-1}) \\ \mathrm{Gy},\ \mathrm{Sv},\ (\mathrm{m}^2 \cdot \mathrm{s}^{-2}) \\ \mathrm{J},\ \mathrm{N} \cdot \mathrm{m},\ (\mathrm{kg} \cdot \mathrm{m}^2 \cdot \mathrm{s}^{-2}) \end{aligned}$$

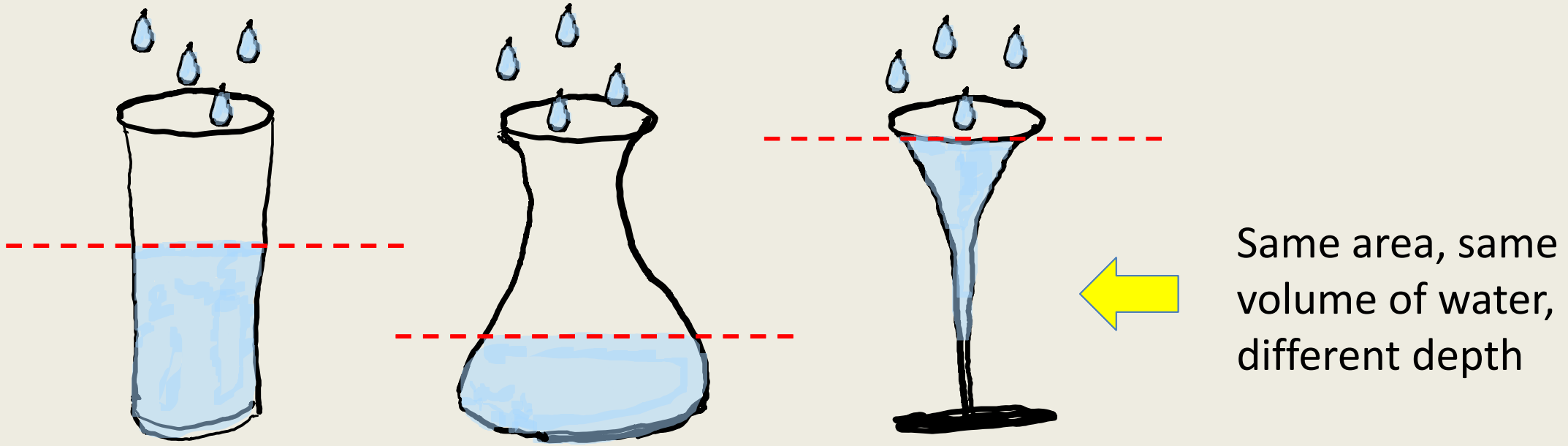
$$\begin{aligned} 15\,\mathrm{N} \cdot \mathrm{m} &\rightarrow 15\,\mathrm{J} \quad \text{(energy)} \\ &\not\rightarrow 15\,\mathrm{J} \quad \text{(torque)} \end{aligned}$$

$$\begin{aligned} 1.5\,\mathrm{s}^{-1} &\rightarrow 1.5\,\mathrm{Hz} \quad \text{(frequency)} \\ &\not\rightarrow 1.5\,\mathrm{Hz} \quad \text{(activity)} \end{aligned}$$

What kind of quantity is that again?

Sometimes we think that a unit like **metre** MUST be a measure of **length**, but it is not always so. Units represent scaling not quantities.

Rainfall is just one example.



Same area, same volume of water, different depth

Beyond quantity kinds—the problem of temperatures

In quantity calculus, a sum or difference is only allowed between terms of the same quantity kind and then the result is of the same kind.

So, temperature difference is the same kind of quantity as temperature.

But, when transforming expressions of temperature,
the distinction is necessary

Need aspects for temperature and temperature difference

Here, aspect is more specialised than quantity kind

$12\,°\mathrm{C} = ??$ $\qquad 12\,\mathrm{K} \quad \text{or} \quad 285.15\,\mathrm{K}$

Celsius temperature: $\quad T/\mathrm{K} = t/°\mathrm{C} + 273.15$

Temperature difference: $\quad \Delta T/\mathrm{K} = \Delta t/°\mathrm{C}$

Dimensionless ratios—are they quantities?

Quantity calculus considers ‘dimensionless’ quantities as pure numbers

For ratios of the same quantity, SI unit notation that shows a ratio is encouraged

The M-layer defines distinct aspects for dimensionless quantities
(length-ratio, voltage-ratio, etc.)

These aspects are more specific than quantity kinds, but they are as general as possible for the ratioed quantity

$$110\ \frac{\mathrm{V}}{\mathrm{V}} \longrightarrow\ 110$$

$$\overset{???}{\longrightarrow}\ 110\ \frac{\mathrm{m}}{\mathrm{m}}$$

Non-linear functions

"The ratio of two quantities of the same kind and any function of that ratio, such as the logarithm of that ratio, are different quantities, although they describe the same physical situation" — ISO 80000-1:2013 (sec. 6.2)

A change of base scales (converts) data

Zero remains zero

The aspect of a logarithmic ratio is independent of the base

Here aspect is more general than quantity-kind (according to ISO 80000)

$$\log_b(x) = \log_b(e)\,\log_e(x)$$

so

$$\log_{10}(x) = \log_{10}(e)\,\log_e(x)$$

and so

$$\log_{10}(x) = 0.434\,\log_e(x)$$

Summary

- The M-layer uses a pair of unique identifiers to label each form of expression—one is an aspect identifier, and the other is a scale identifier

- Aspect is closely related to quantity kind, but serves a different purpose

- Aspect and quantity kind are often, but not always, the same

  - Sometimes aspect is more specialised (e.g., temperature-difference and quantity ratios);
  - Sometimes aspect is more general (e.g., logarithmic ratios)

- The aspect is always the most general measurable property (quantity) needed to uniquely identify an expression format (in combination with a scale identifier)

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Thank you ☺

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Additional information

1. B. D. Hall and M. Kuster, *Representing quantities and units in digital systems*, Measurement: Sensors, 2022, 23, 100387. DOI:10.1016/j.measen.2022.100387

2. B. D. Hall, *The problem with 'Dimensionless Quantities'*, In Proceedings of the 10th International Conference on Model-Driven Engineering and Software Development - MODELSWARD, 2022, ISBN 978-989-758-550-0, pages 116-125. DOI: 10.5220/0010960300003119.

3. B. D. Hall, *Representing and expressing measurement data in digital systems*, Springer-Nature Computer Science, 4(2), 120 (2023). DOI:10.1007/s42979-022-01534-x

4. B. D. Hall, *Modelling expressions of physical quantities*, in: Proceedings of the 15th International Conference on Knowledge Engineering and Ontology Development (IC3K 2023) – Volume 2: pages 216 – 223, ISBN: 978-989-758-671-2; ISSN: 2184-3228; DOI: 10.5220/0000178400003598.

5. B. D. Hall, P. Saunders, and D. R. White, *Representation of scales and units for temperature and related quantities*, Temperature: Its Measurement and Control in Science and Industry, Vol 10, (in press—preprint available)