Calculus learning goals for thermodynamics and the Partial Derivative Machine

David Roundy Liz Gire Tevian Dray Corinne Manogue

Oregon State University

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Learning goals

Thick understanding of derivative

1. A ratio of small changes.
2. ... is small infinitesimal?
3. Both a number (or value) and a function.
4. Can be related to experiments.

Partial derivatives

1. Thermal state variables are not functions.
2. Some variables are dependent on others, with a choice as to which to treat as independent.
3. What is held fixed matters, and is not obvious.
4. Partial derivatives can be related to experiments.

Papers

Roundy, Dray, Manogue, Wagner and Weber, "An extended theoretical frameword for the cencept of derivative," RUME Proceedings (2015).

Roundy, Weber, Dray, Bajracharya, Dorko, Smith and Manogue, "Experts' understanding of partial derivatives using the partial derivatives machine," PRSTPER (2015).

Kustusch, Roundy, Dray and Manogue, "Partial derivative games in thermodynamics: A cognitive task analysis," PRSTPER (2014).

Roundy, Kustusch and Manogue, "Name the Experiment! interpreting thermodynamic derivatives as thought experiments," AJP (2014).

Roundy and Rogers, "Exploring the thermodynamics of a rubber band," AJP (2013).

Differentials & First Law

1. Differentials relate small changes.
2. ... is small infinitesimal?
3. Small changes can add up to large changes.
4. We have a choice of path.

$$dU = F_1 dx_1 + F_2 dx_2$$

Legendre transforms

1. Legendre transforms are useful when information is hidden or properties are fixed.
2. "Free energy" for the PDM includes the gravitational potential energy of a hanging weight.

$$A = U - F_2 x_2$$

3. The change in "free energy" with one weight fixed is the work done on the other side.

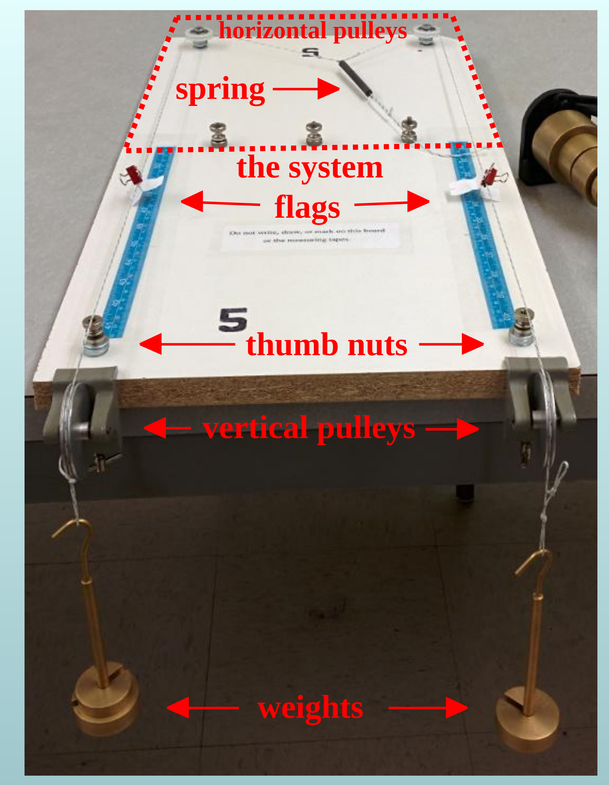
$$dA = F_1 dx_1 - x_2 dF_2$$

Instructions to build a PDM:

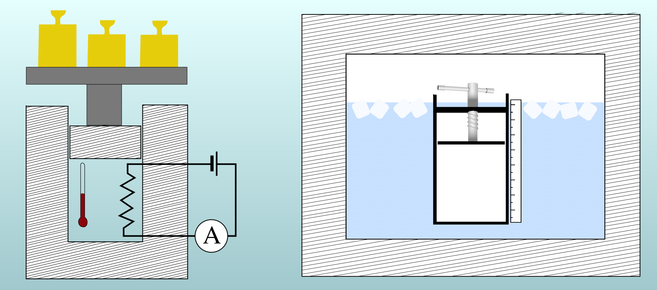
http://www.physics.oregonstate.edu/portfolioswiki/whitepapers:pdm:start

Activities

Partial Derivatives Machine



Name the Experiment!



Ice and rubber band experiments