Thermodynamics lecture 2.

W.A.L.T. (we are learning today)

- Some mathematical methods with partial differentiation and functions of state.
- Zeroth law → temperature and equation of state

Function of state ←→ proper differential

Pressure p

Volume V

Temperature T

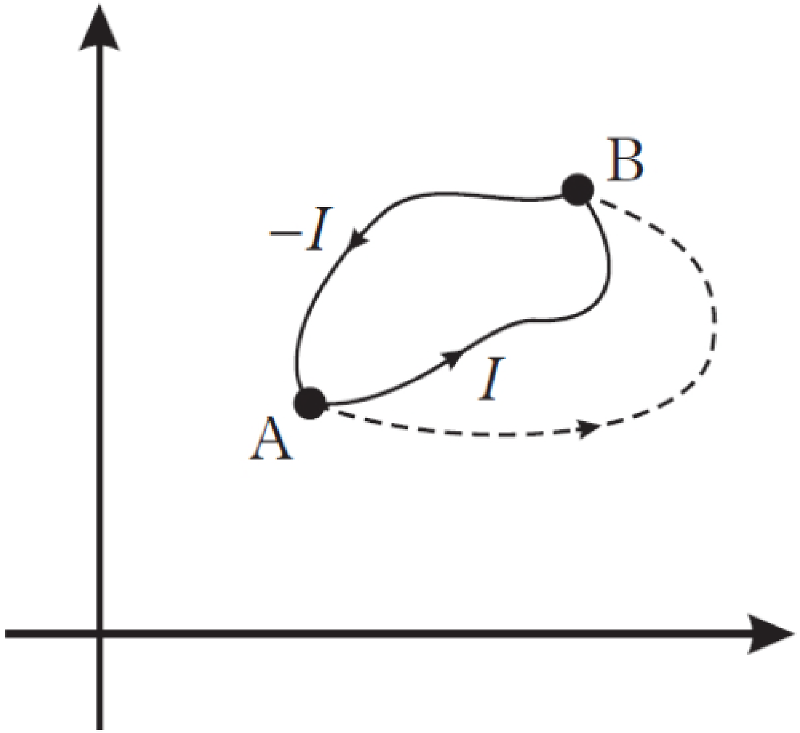
$\mathrm{d}p, \mathrm{d}V, \mathrm{d}T$

Not function of state ←→ improper differential

Work W

Heat Q

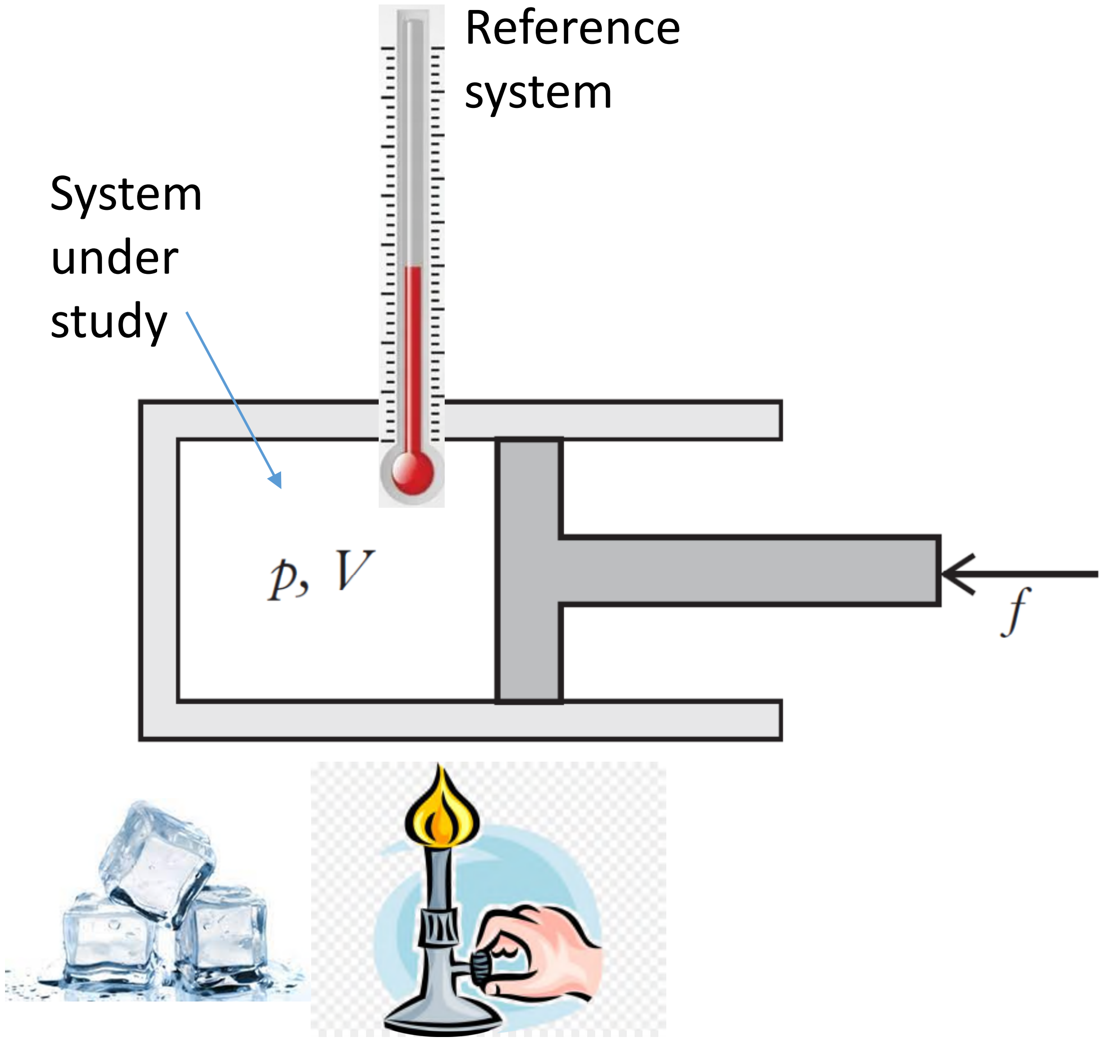
$đW, đQ$

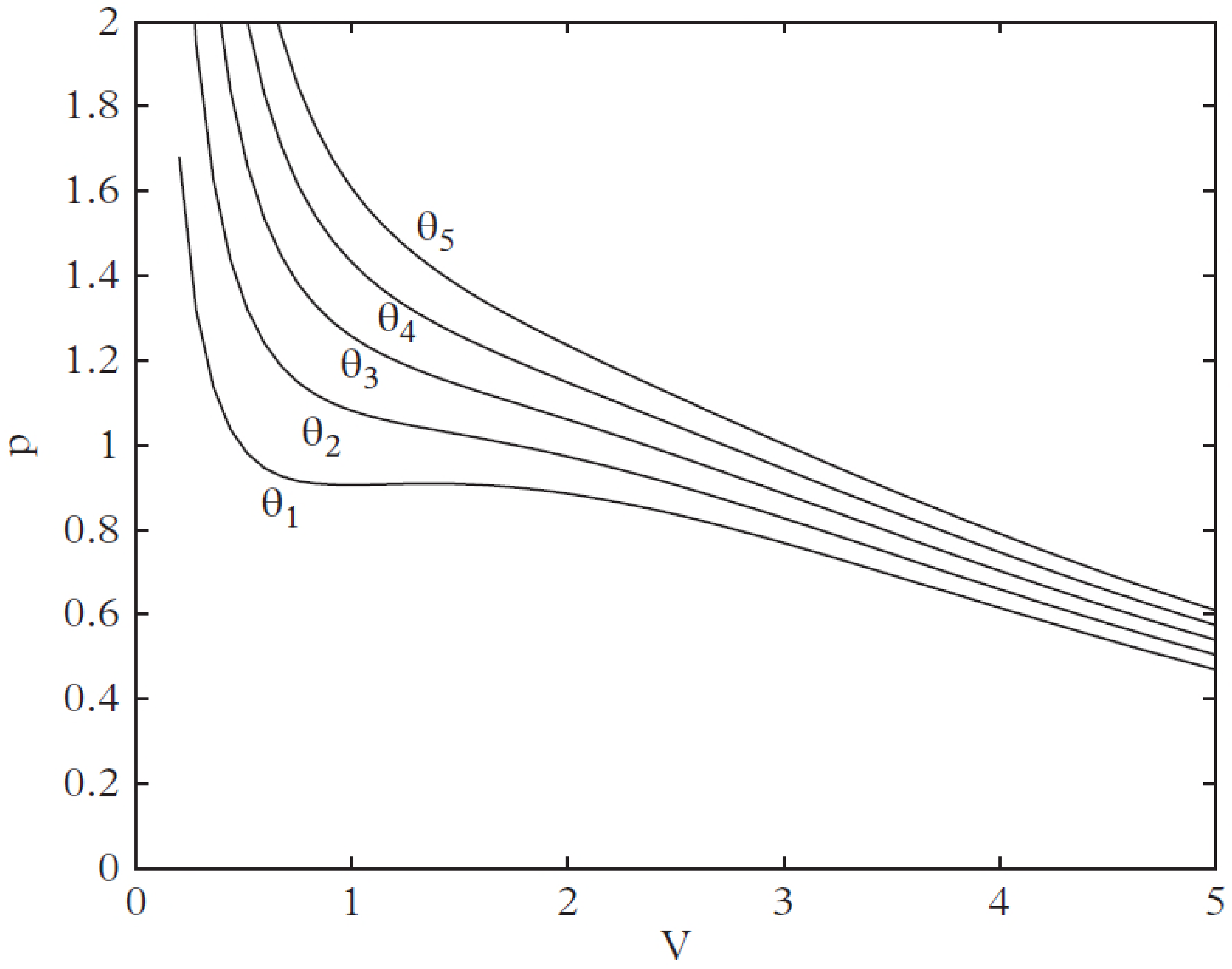


Theorem:

If the integral of a function *f* is zero around all closed paths, then *f* is a function of state.

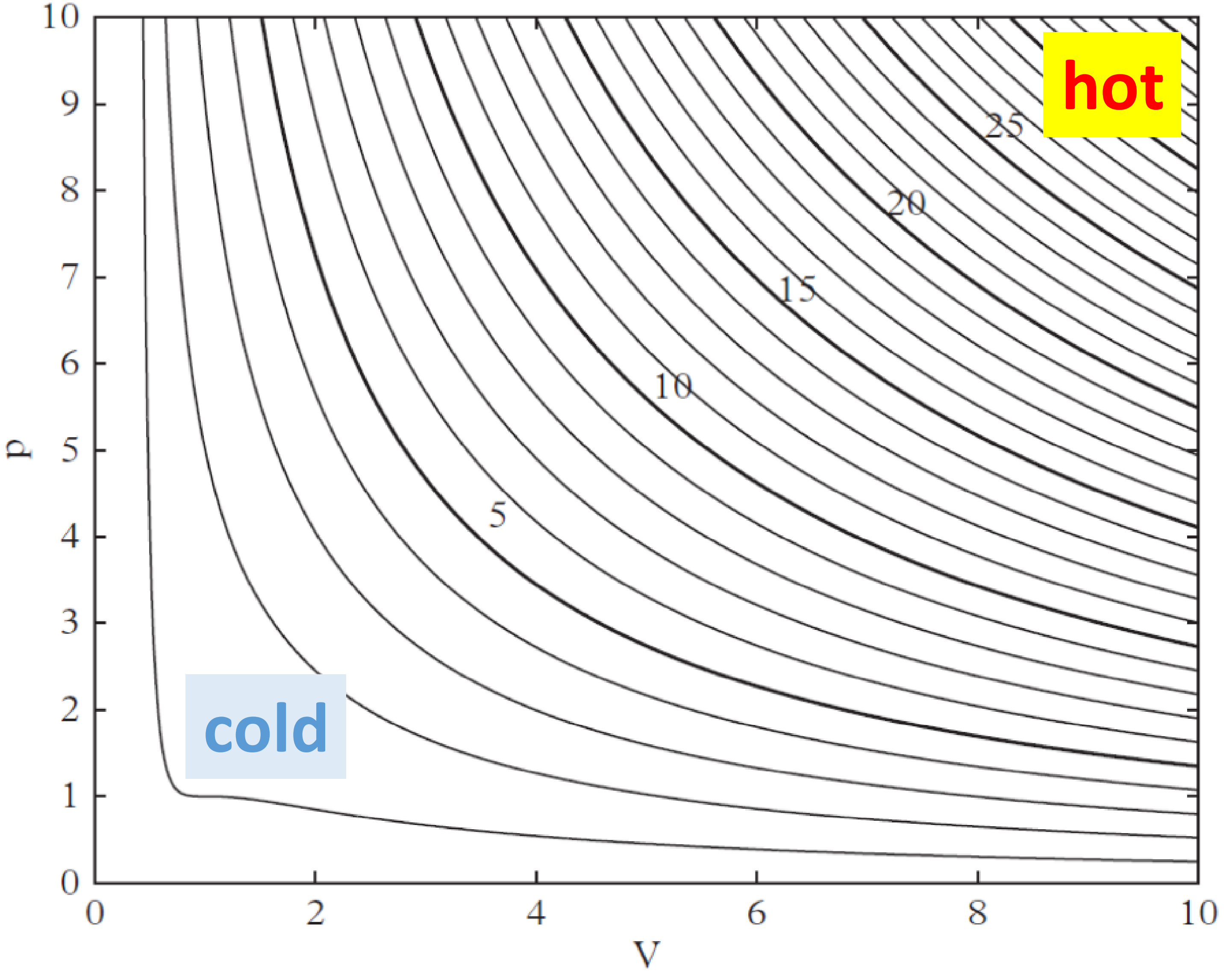
Zeroth law, empirical temperature and equation of state


Reference system
System under study
p, V
f


p
V
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1
2
3
4
5
θ_1
θ_2
θ_3
θ_4
θ_5

van der Waals equation of state (reasonably accurate for most gases if the pressure is not too high)

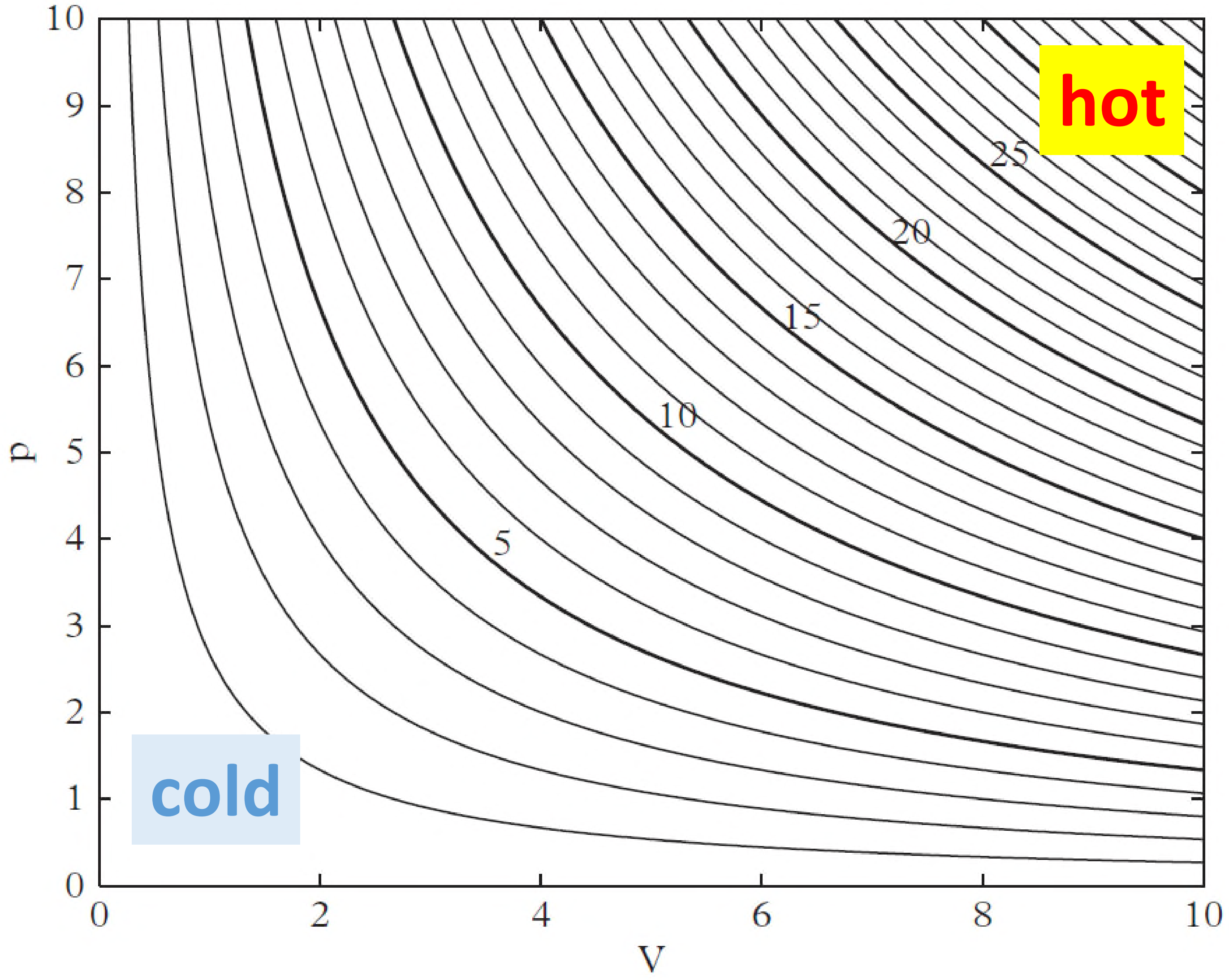
$$\left(p + \frac{N^2 a}{V^2}\right)(V - Nb) = N k_B T$$



Isotherms of **van der Waals** gas, in the gaseous (not liquid) region

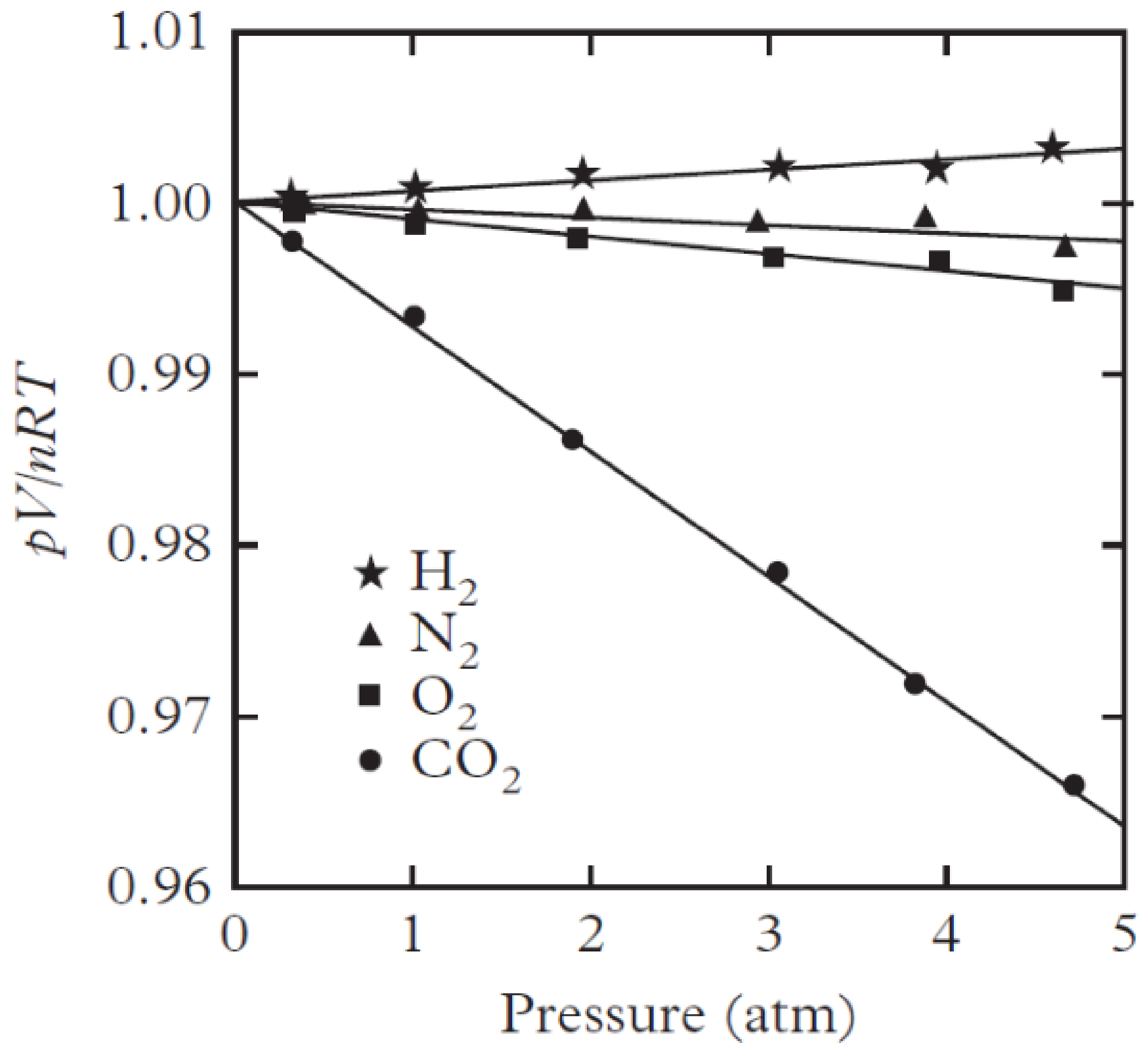
Ideal gas

$$pV = Nk_B T$$



Isotherms of **ideal** gas

Real gases tend to ideal at low pressure



Definition of an ideal gas

(1) *Boyle's law: pV is constant at fixed temperature.*
(2) *Joule's law: The internal energy is independent of pressure at fixed temperature.*

(1) Implies $pV = f(T)$ for some function f.

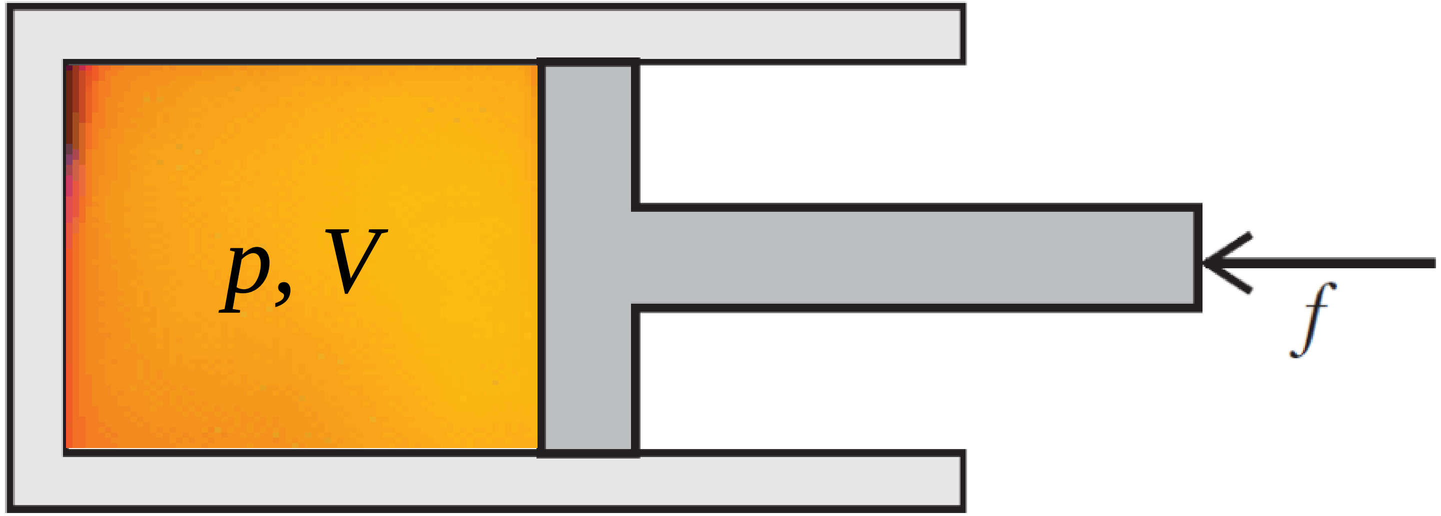
(2) Is often written $U = U(T)$.

We will show later that (1) and (2) together imply f = const x T,

hence $pV = Nk_B T$

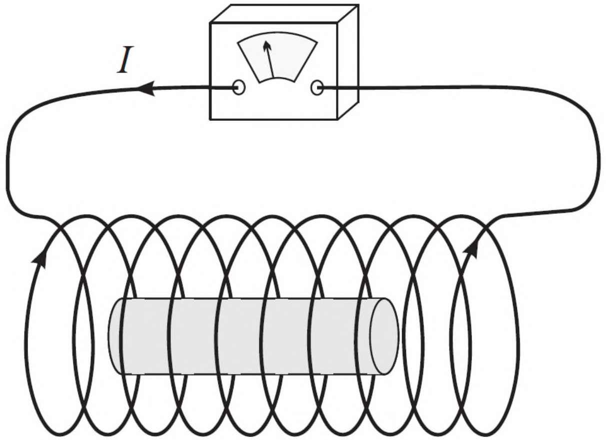
Thermal radiation

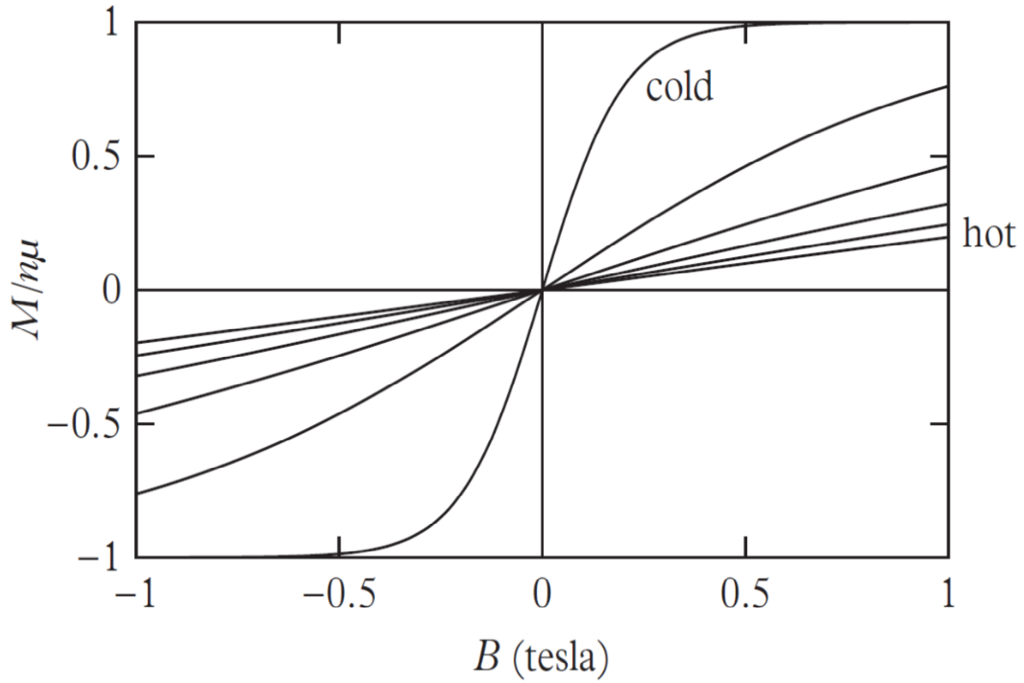
electromagnetic waves in a cavity in equilibrium at temperature T.



Equation of state: $p = aT^4$

Paramagnetism





State can be specified by $\mathbf{M}$, $\mathbf{B}$, where *magnetization* $\mathbf{M}$ = magnetic dipole moment per unit volume.

Let $$\mathbf{H} \equiv \frac{1}{\mu_0}\mathbf{B} - \mathbf{M}$$

Then for paramagnet, $\mathbf{M} = \chi\, \mathbf{H}$

where χ is called *magnetic susceptibility*.

Example equation of state:

Curie's law $$\mathbf{M} = \frac{a}{T}\mathbf{H}$$