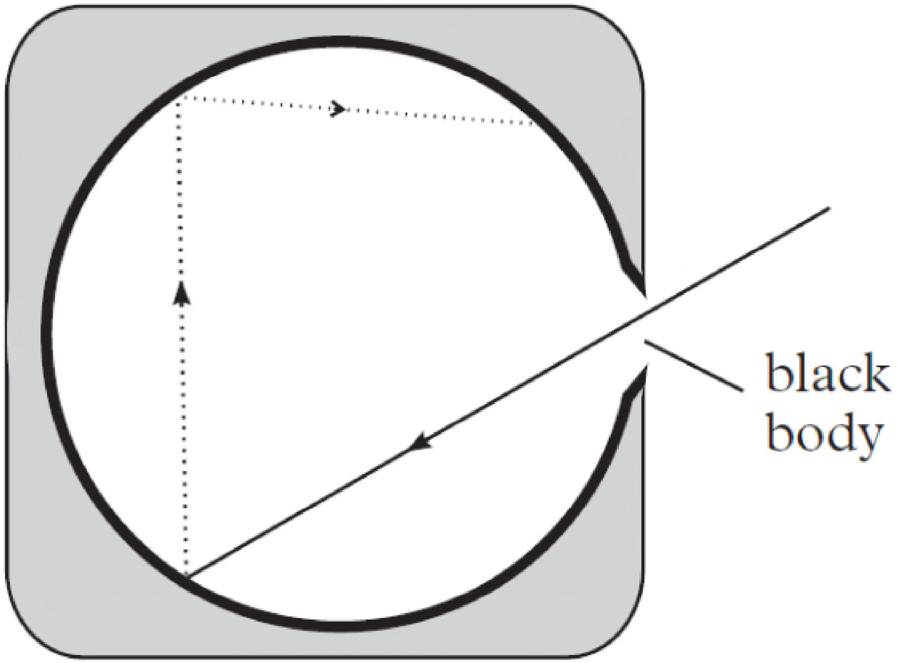
Thermodynamics lecture 8.

Thermal radiation 1: thermodynamic arguments

1. Black body and UNIVERSALITY of cavity radiation
2. Kirchoff’s Law
3. Equation of state and Stefan-Boltzmann law
4. Entropy, heat capacity, Gibbs function



Constructing a black body (to good approximation) using a hole in a highly absorbent chamber.

Stefan-Boltzmann Law:

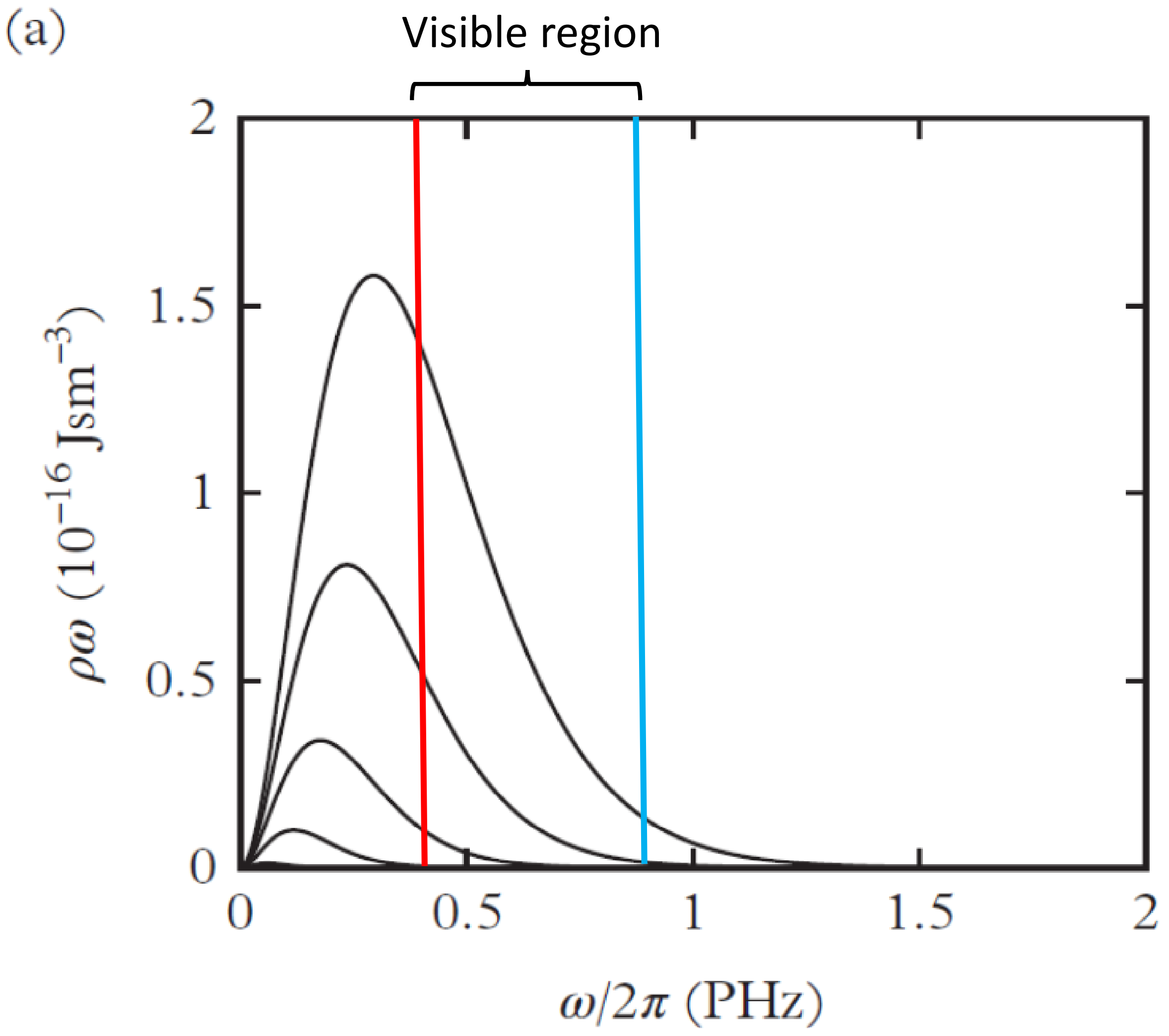
Power emitted from surface area A of a black body in thermal equilibrium at temperature T is

$$P = \sigma A T^4,$$

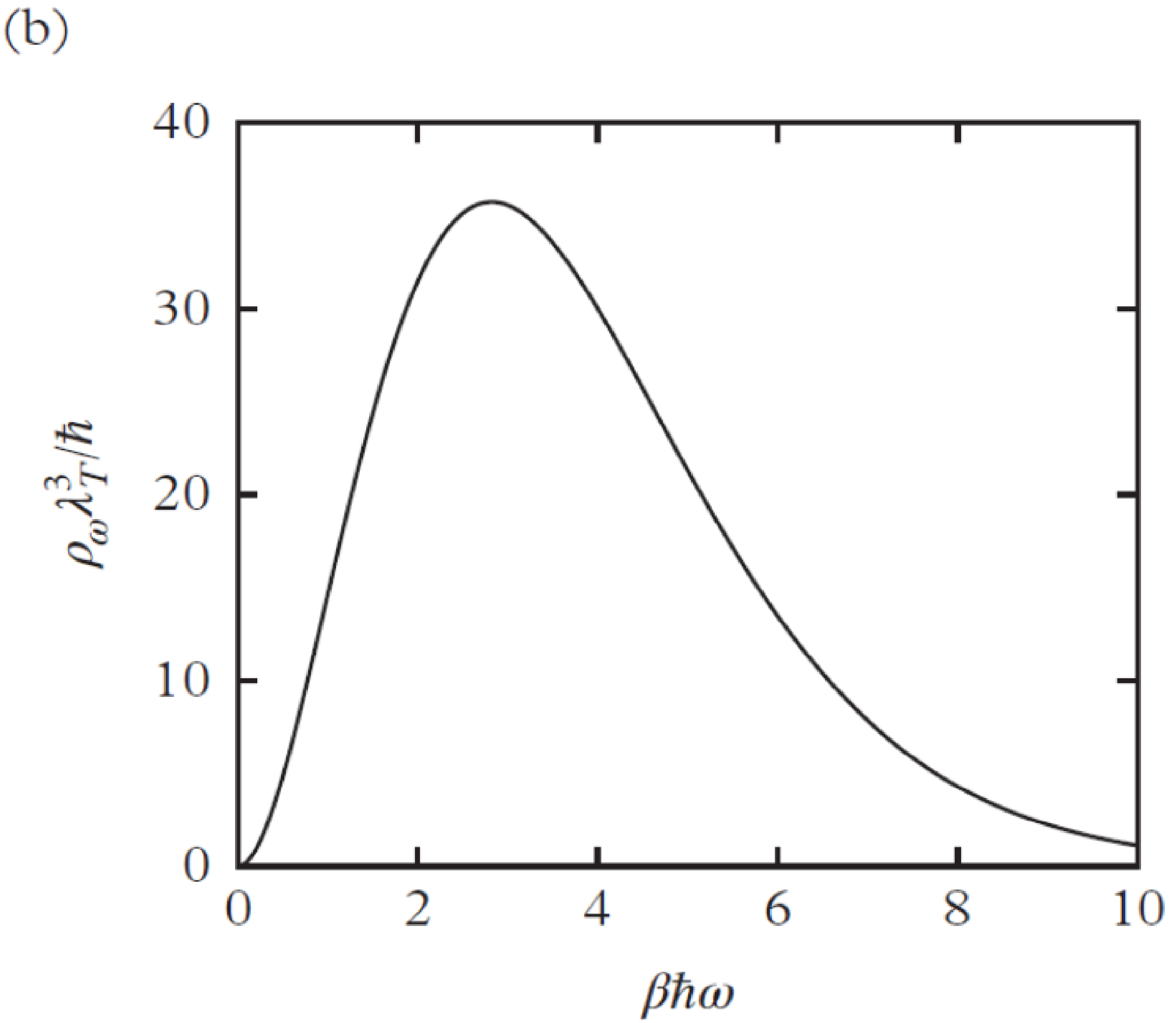
where the *Stefan-Boltzmann constant* is

$$\sigma = \frac{\pi^2 k_B^4}{60\hbar^3 c^2} \simeq 5.6704 \times 10^{-8}\ \mathrm{W m^{-2} K^{-4}}$$

→ About 400 watts per metre-squared at room temperature.

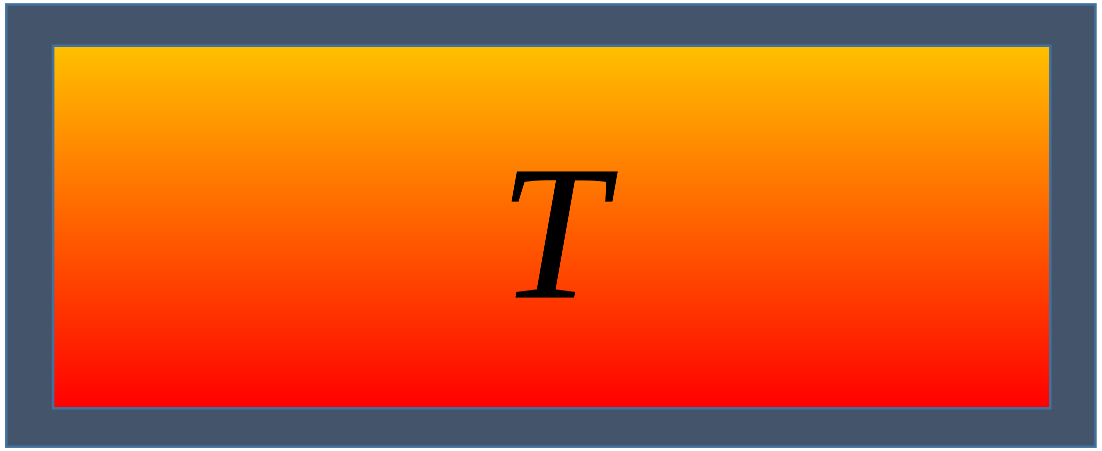


Spectral energy density at
1000, 2000, 3000, 4000, 5000 K



It's essentially the same function each time, scaled by λ_T^3

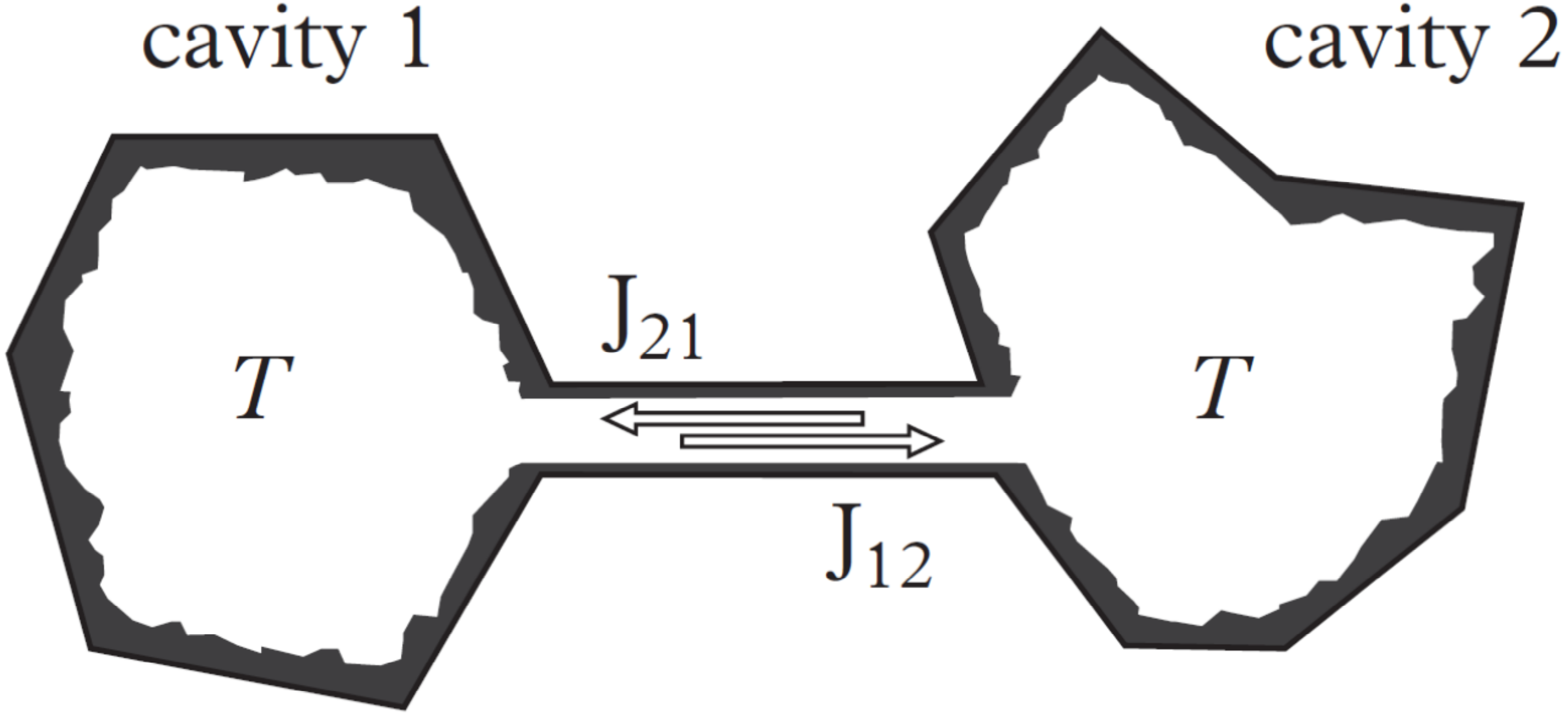
$$\lambda_T = 2\pi\hbar c/k_B T.$$

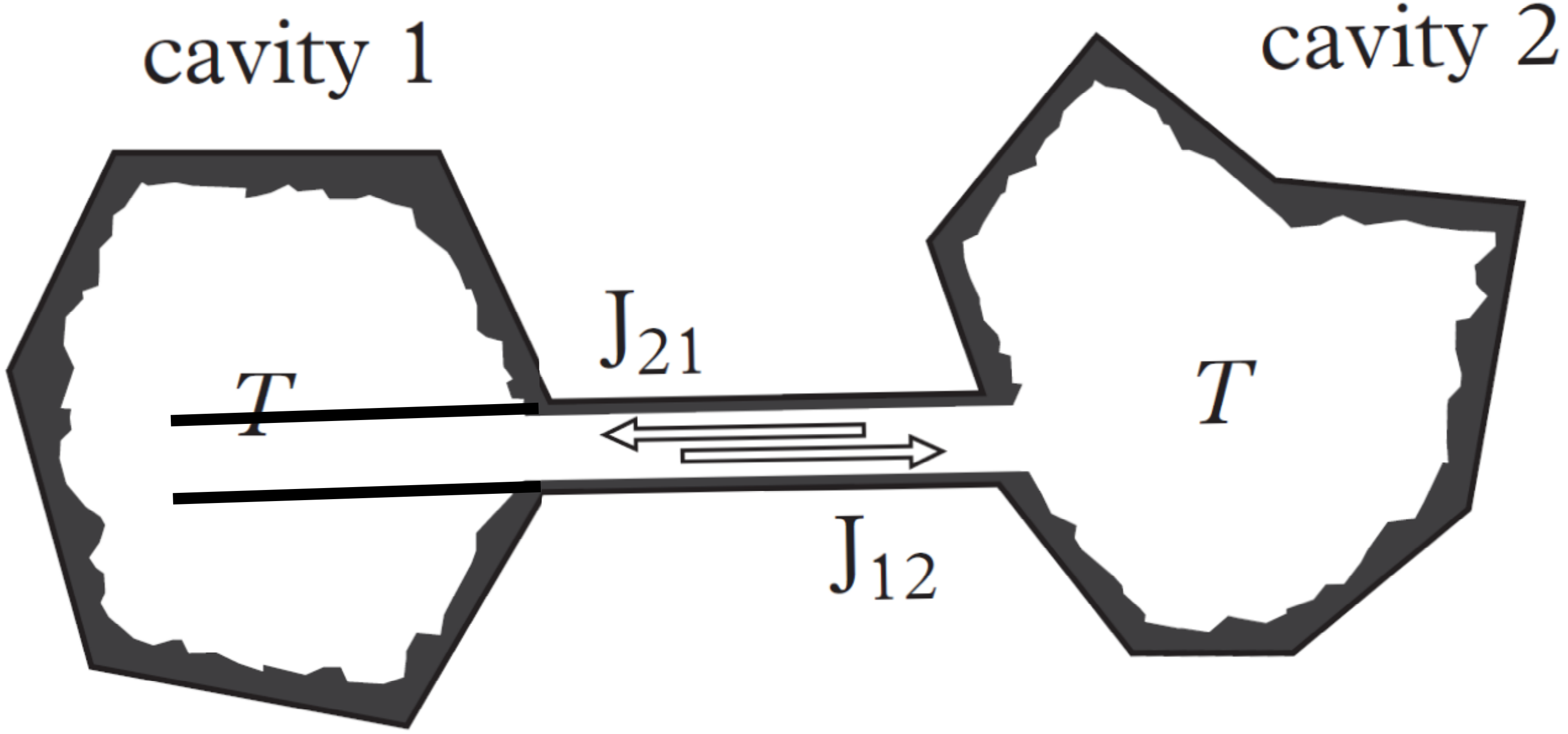


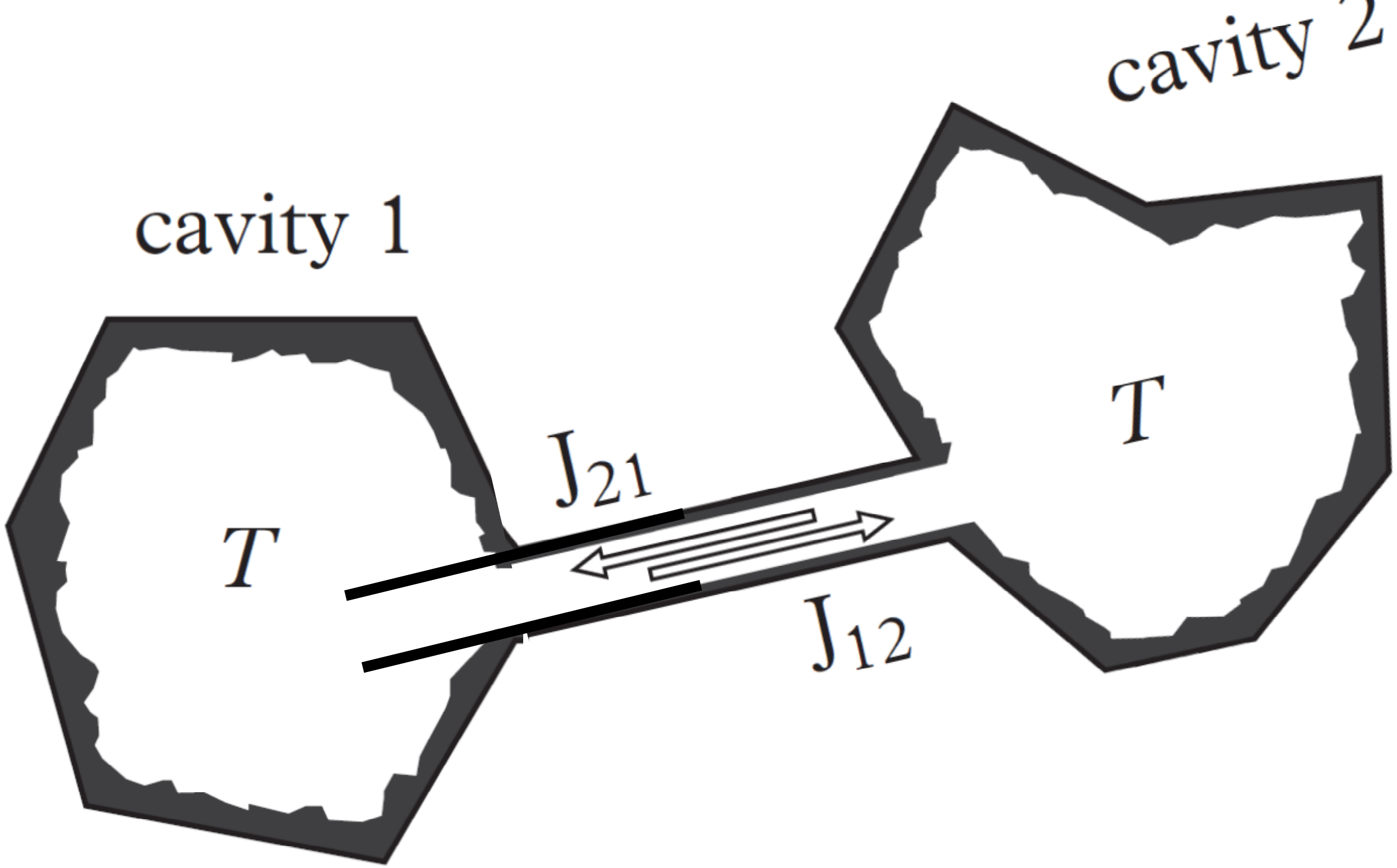
Cavity radiation = the electromagnetic radiation inside an otherwise empty cavity in thermal equilibrium

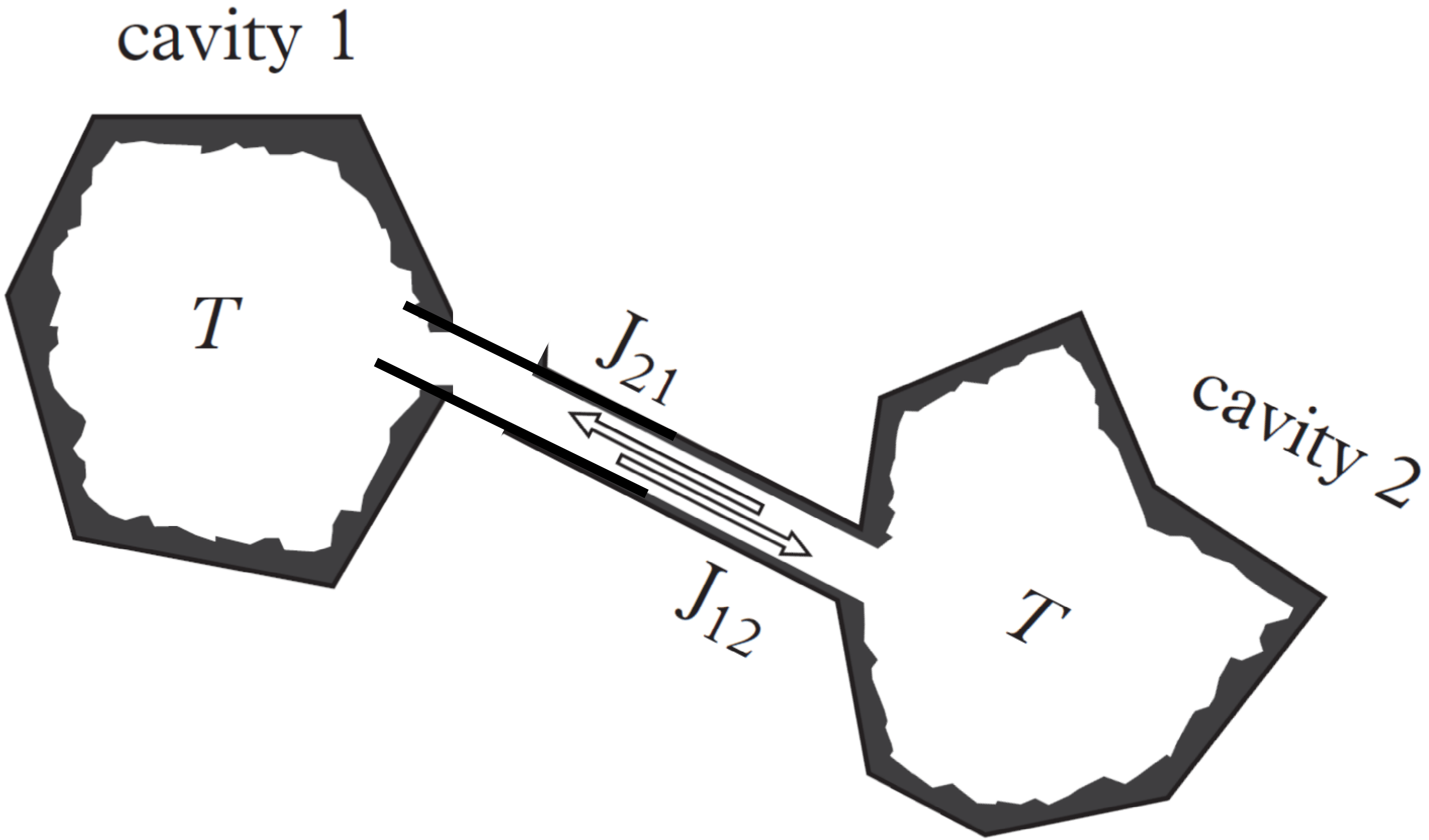
We will prove that, for a LARGE cavity with OPAQUE walls,

1. Cavity radiation is **universal** (depends only on T)
2. Cavity radiation = black body radiation (i.e. same energy density and other properties.)


cavity 1
cavity 2
T
T
J21
J12

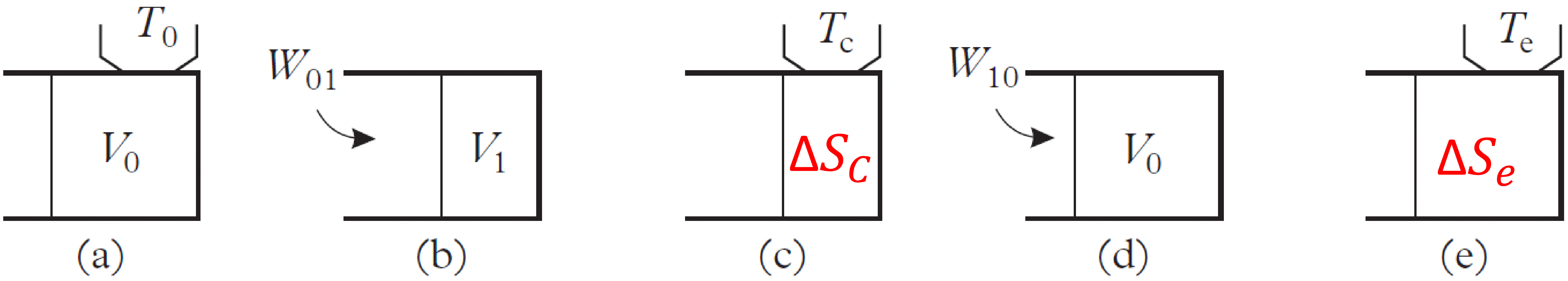

cavity 1
cavity 2
J21
J12
T
T


cavity 2
cavity 1
T
T
J21
J12


cavity 1
T
J21
J12
T
cavity 2

Adiabatic expansion of cavity radiation: does it remain in thermal equilibrium state?

Wien's argument to show the answer is *yes*:



Stages (a), (c) and (e) :
Come to equil (at some temperature or other) with no net ΔU

Stages (b) and (d):
Do work or receive work, adiabatically