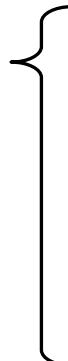


01. What is "Information"?

- Common notions:
 - Knowledge: the more you know, the more "information" you have
 - A physical substance?
 - An abstract concept?
 - Data
 - Bits, binary digits, digital technology
- Technical notions:
 - Shannon information  information associated with classical information theory (classical communication protocols)
 - Fisher information  information associated with statistical analysis
 - Quantum information  information associated with quantum communication protocols

Plan of course:

Part I: Information in Classical Information Theory and Statistics

- Shannon information = the "surprise-content" of a value of a *random variable* X .
- Shannon entropy $S_{\text{Shan}}(X)$ = a measure of the average Shannon info of X .  *intrinsically probabilistic!*
- Bit = 
 - amount of Shannon info in a *binary random variable* X  *math senses*
 - value of a binary random X
 - 2-state classical system  *physics senses*
 - state of 2-state classical system
- Fisher information = the average "sensitivity" of an estimate of an unknown parameter to changes in that parameter.

Is Shannon information the same as Fisher information?

Part II: Information in Thermodynamics and Statistical Mechanics

- Thermodynamic entropy $S_{TD}(\sigma)$ = a property of a physical system undergoing a reversible process between equilibrium states.

- 2nd Law of Thermodynamics:

S_{TD} never decreases for a thermally isolated system.

Is S_{TD} the same as S_{Shan} ?

Can the 2nd law be formulated in terms of S_{Shan} ?

- Boltzmann entropy $S_{Boltz}(\Gamma_M)$ = the size of a region Γ_M in a system's phase space.

Is S_{Boltz} the same as S_{TD} and/or S_{Shan} ?

- Gibbs entropy $S_{Gibbs}(\rho)$ = a property of a Gibbs distribution ρ on a system's phase space.

- S_{Shan} is formally identical to S_{Gibbs} !

← Motivation for S_{Shan} !

- Maxwell's Demon

- Can the 2nd Law be violated by a physical system?
- What if the system is a computational device that *stores* or *erases* "information"?

⚡
Szilard's Principle:
Acquiring "information"
costs S_{TD}

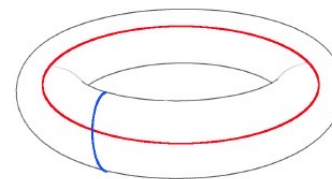
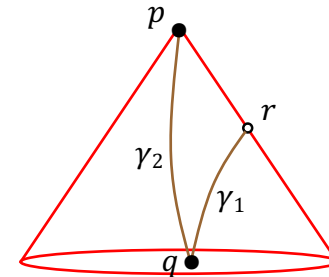
⚡
Landauer's Principle:
Erasing "information"
costs S_{TD}

Part III: Information in Quantum Mechanics

- von Neumann entropy S_{vN} = a measure of how "mixed" a quantum state is.
 - S_{vN} is formally equivalent to S_{Gibbs} and hence S_{Shan} !  *Is mixedness related to Shannon information?*
- Qubit = 
 - amount of "quantum info" in a 2-dim operator
 - eigenvalue of a 2-dim operator  *math senses*
 - 2-state quantum system
 - state of 2-state quantum system  *physics senses*
- Qubit transmission protocols
 - Dense coding, teleportation.  *Things you can do with qubits that you can't do with bits.*
- Qubit protection protocols
 - Quantum error correction codes.  *Qubit protection is more robust than bit protection!*
- Is "quantum information" distinct from "classical information"?
 - *Shannon information?*
 - *Fisher information?*

Part IV: Information in Spacetime Physics

- Theoretical limits on Turing computability  *A precise notion of computability*
 - The halting problem
 - The decision problem for 1st order logic
 - The decision problem for 1st order arithmetic
- Relativistic spacetimes and computability
 - Does the relativistic structure of spacetime affect theoretical limits on Turing computability?
- Topology and quantum error correction
 - Does the topological structure of spacetime affect ways of protecting qubits?



Part V: Information-Theoretic Physics?

- Spacetime as a quantum error correction code?  *AdS/CFT approach to quantum gravity suggests it is!*
- Physics from quantum information?  *Can quantum mechanics be formulated in terms of quantum information principles?*
- Physics from Fisher information?
 - Fisher information = a measure of the accuracy of estimates of an unknown parameter. *Can the equations of physics (both quantum and classical!) be derived from Fisher information principles?*