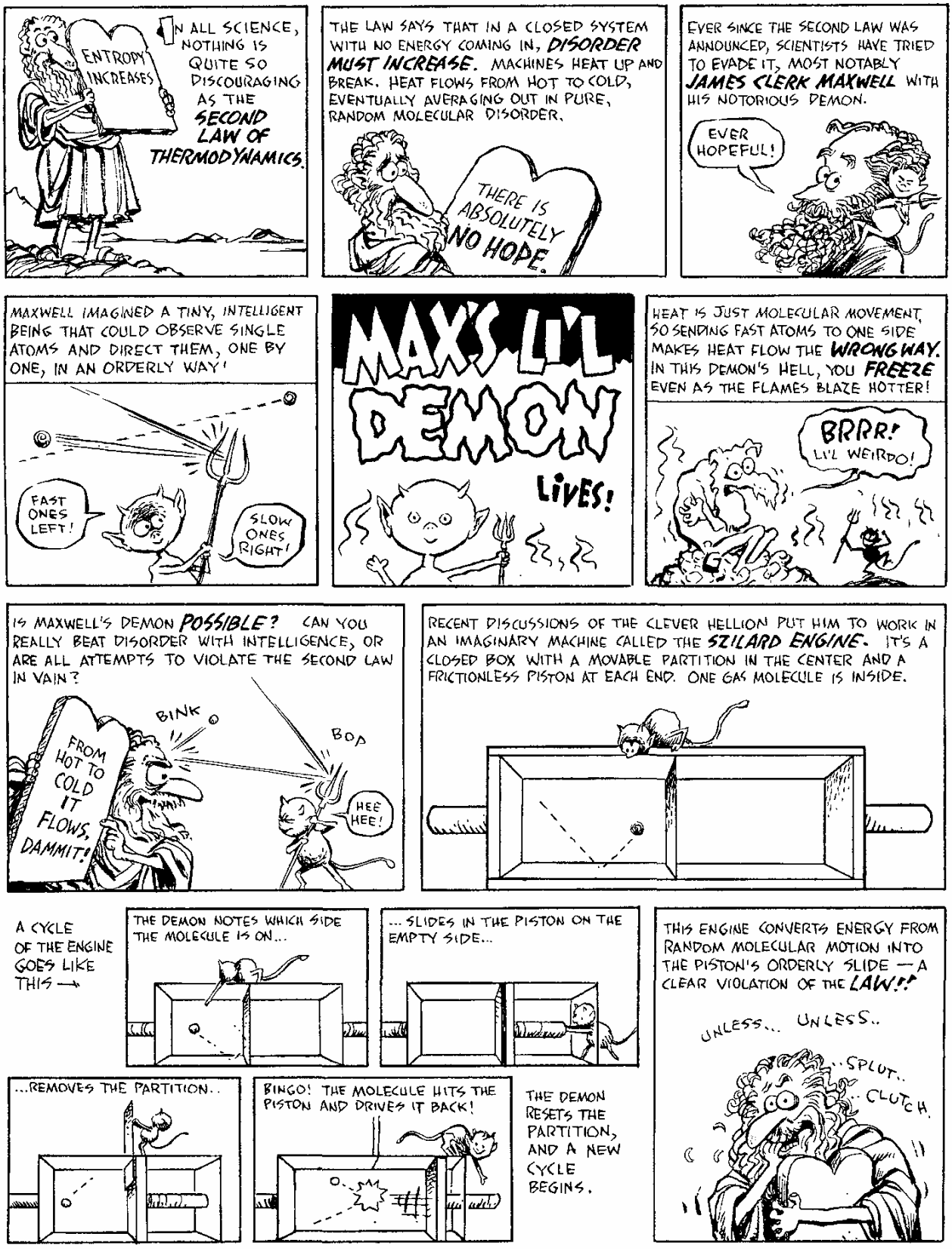
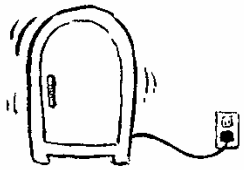
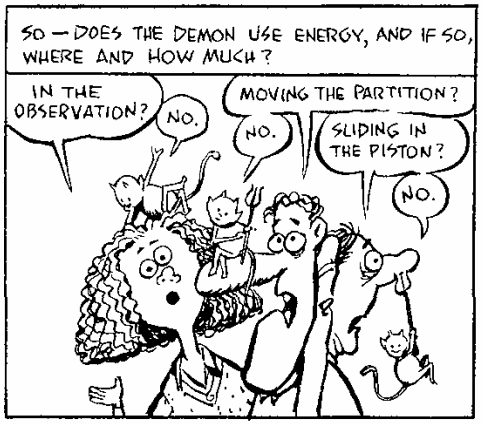


C.H. Bennett „Information physics in cartoons”

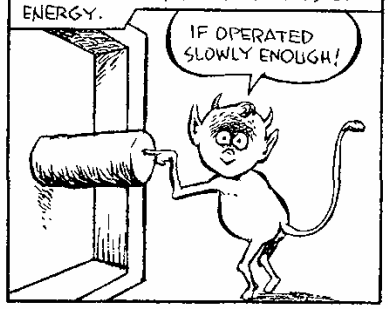
UNLESS, THAT IS, THE IMP PUT SOME ENERGY INTO THE SYSTEM! REMEMBER, THE 2ND LAW IS GOOD ONLY IN **CLOSED SYSTEMS.** IF YOU ADD ENERGY, ALL BETS ARE OFF! YOUR **REFRIGERATOR** CAN MAKE WARM THINGS COLDER, BUT ONLY BECAUSE IT'S PLUGGED INTO AN OUTSIDE ENERGY SOURCE.



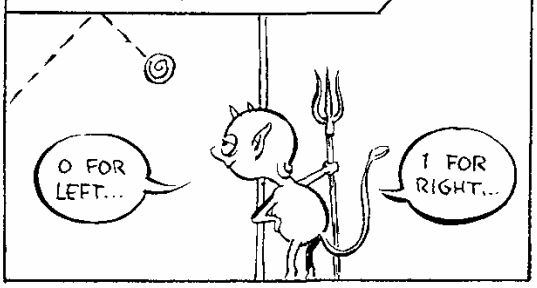
SO — DOES THE DEMON USE ENERGY, AND IF SO, WHERE AND HOW MUCH?



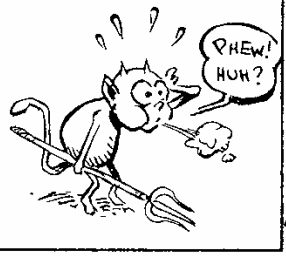
CAREFUL ANALYSIS SHOWS THAT ALL MOVING PARTS OF THE SZILARD ENGINE CAN BE MADE TO USE VANISHINGLY SMALL AMOUNTS OF ENERGY.



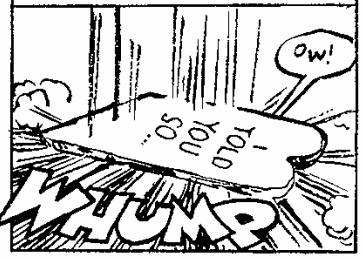
NO...THE INESCAPABLE ENERGY REQUIREMENT IS FOR **INFORMATION PROCESSING.** THE DEMON BEGINS BY REGISTERING THE STATE OF THE SYSTEM, WHICH USES **ONE BIT** OF STORAGE: THE MOLECULE IS EITHER ON THE RIGHT OR THE LEFT.



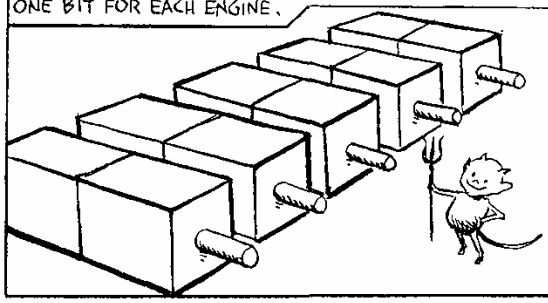
WHAT CONSUMES ENERGY IS **ERASING** THAT BIT TO RESET THE SYSTEM. **FORGETTING IS WORK!**



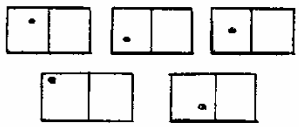
IBM INFORMATION SCIENTIST **ROLF LANDAUER** HAS COMPUTED THAT THE ENERGY NEEDED TO ERASE ONE BIT MUST EXCEED THE AVERAGE ENERGY EXTRACTED BY THE MOVING PISTON. THE 2ND LAW LIVES!



BUT OPTIMISM DIES HARD.. IN 1990, **CARLTON CAVES** OF **USC** THOUGHT HE HAD FOUND A WAY OUT: HE CONSIDERED A SERIES OF SZILARD ENGINES, FIVE FOR EXAMPLE. NOW THE DEMON NEEDS A **FIVE**-BIT MEMORY, ONE BIT FOR EACH ENGINE.

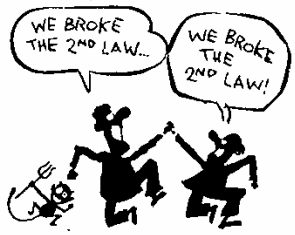


CAVES REASONED THAT THE MINUSCULE FIEND COULD WORK THE ENGINES ONLY IN CERTAIN "RARE" CONFIGURATIONS — SAY, WHEN ALL MOLECULES ARE ON THE LEFT.



THIS WOULD USE ONLY **ONE** BIT OF MEMORY — THEY'RE ALL ON THE LEFT, OR ELSE **NOT.**

THIS WOULD USE LESS ENERGY, BUT THE **OUTPUT** WOULD BE THAT OF **FIVE** SZILARD ENGINES. CAVES WAS DELIGHTED, AND SO WERE THE EDITORS OF *PHYSICAL REVIEW LETTERS!!*



CAVES HAD CONVENIENTLY FORGOTTEN THAT THE DEMON WOULD FIRST HAVE TO DECIDE WHETHER A CONFIGURATION WAS "RARE." THIS EXTRA INFORMATION COST EXACTLY CANCELED THE ADVANTAGE HE THOUGHT HE'D GAINED!

IT SEEMS THE LAW IS SAFE... EVERYTHING REALLY **WILL** DECAY... AND THE ONLY **PERPETUAL MOTION MACHINE** IS THE NEVER-ENDING EFFORT OF SCIENTISTS AND CRANKS TO THINK UP NEW ONES...