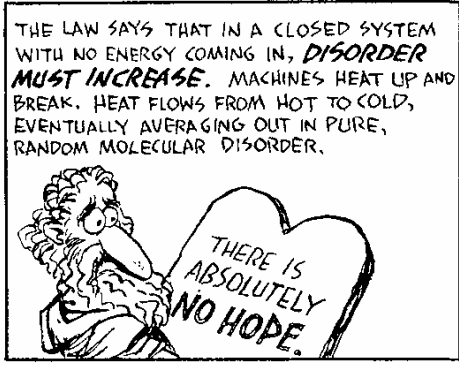
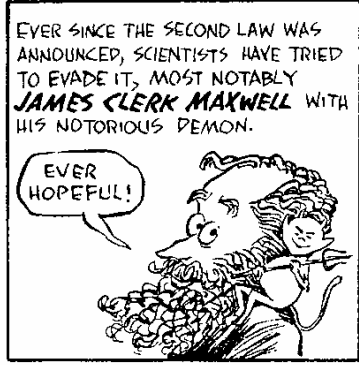


IN ALL SCIENCE, NOTHING IS QUITE SO DISCOURAGING AS THE **SECOND LAW OF THERMODYNAMICS**.



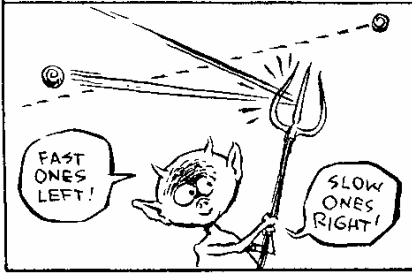
THE LAW SAYS THAT IN A CLOSED SYSTEM WITH NO ENERGY COMING IN, **DISORDER MUST INCREASE**. MACHINES HEAT UP AND BREAK. HEAT FLOWS FROM HOT TO COLD, EVENTUALLY AVERAGING OUT IN PURE, RANDOM MOLECULAR DISORDER.



EVER SINCE THE SECOND LAW WAS ANNOUNCED, SCIENTISTS HAVE TRIED TO EVADE IT, MOST NOTABLY **JAMES CLERK MAXWELL** WITH HIS NOTORIOUS DEMON.

EVER HOPEFUL!

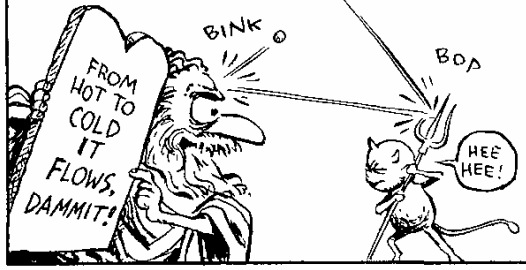
MAXWELL IMAGINED A TINY, INTELLIGENT BEING THAT COULD OBSERVE SINGLE ATOMS AND DIRECT THEM, ONE BY ONE, IN AN ORDERLY WAY!



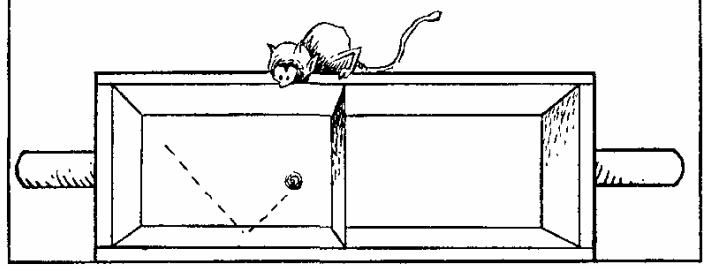
HEAT IS JUST MOLECULAR MOVEMENT, SO SENDING FAST ATOMS TO ONE SIDE MAKES HEAT FLOW THE **WRONG WAY**. IN THIS DEMON'S HELL, YOU **FREEZE** EVEN AS THE FLAMES BLAZE HOTTER!



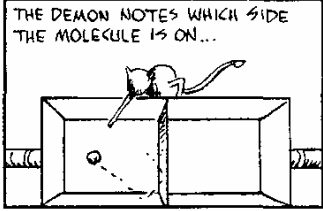
IS MAXWELL'S DEMON **POSSIBLE**? CAN YOU REALLY BEAT DISORDER WITH INTELLIGENCE, OR ARE ALL ATTEMPTS TO VIOLATE THE SECOND LAW IN VAIN?



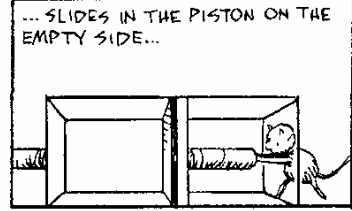
RECENT DISCUSSIONS OF THE CLEVER HELLION PUT HIM TO WORK IN AN IMAGINARY MACHINE CALLED THE **SZILARD ENGINE**. IT'S A CLOSED BOX WITH A MOVABLE PARTITION IN THE CENTER AND A FRICTIONLESS PISTON AT EACH END. ONE GAS MOLECULE IS INSIDE.



A CYCLE OF THE ENGINE GOES LIKE THIS →



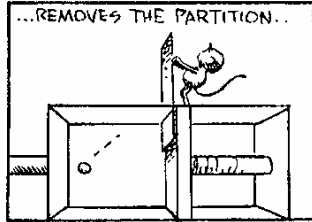
THE DEMON NOTES WHICH SIDE THE MOLECULE IS ON...



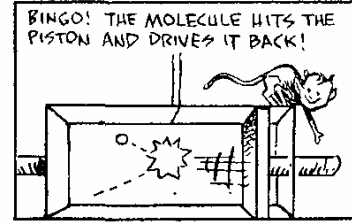
... SLIDES IN THE PISTON ON THE EMPTY SIDE...

THIS ENGINE CONVERTS ENERGY FROM RANDOM MOLECULAR MOTION INTO THE PISTON'S ORDERLY SLIDE — A CLEAR VIOLATION OF THE **LAW!**

UNLESS... UNLESS...



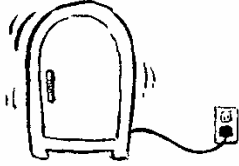
...REMOVES THE PARTITION...



BINGO! THE MOLECULE HITS THE PISTON AND DRIVES IT BACK!

THE DEMON RESETS THE PARTITION, AND A NEW CYCLE BEGINS.

UNLESS, THAT IS, THE IMP PUT SOME ENERGY INTO THE SYSTEM! REMEMBER, THE 2<sup>ND</sup> 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.



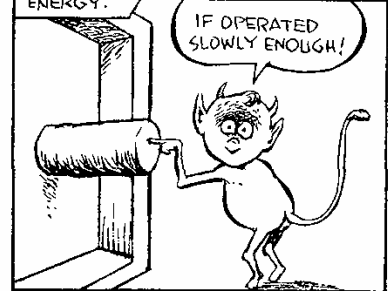
SO — DOES THE DEMON USE ENERGY, AND IF SO, WHERE AND HOW MUCH?

IN THE OBSERVATION? NO. MOVING THE PARTITION? NO. SLIDING IN THE PISTON? NO.

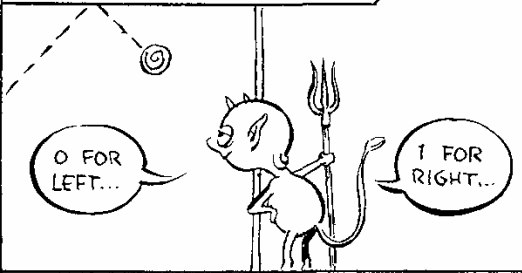


CAREFUL ANALYSIS SHOWS THAT ALL MOVING PARTS OF THE SZILARD ENGINE CAN BE MADE TO USE VANISHINGLY SMALL AMOUNTS OF ENERGY.

IF OPERATED SLOWLY ENOUGH!



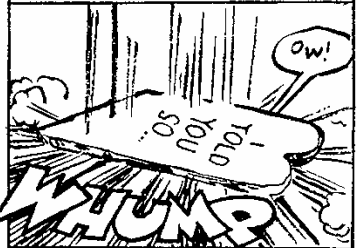
NO...THE INESCAPABLE ENERGY REQUIREMENT IS FOR **INFORMATION PROCESSING**. THE DEMON BEGINS BY REGISTERING THE STATE OF THE SYSTEM, WHICH USES **ONE BIT** OF STORAGE: THE MOLECULE IS EITHER ON THE RIGHT OR THE LEFT.



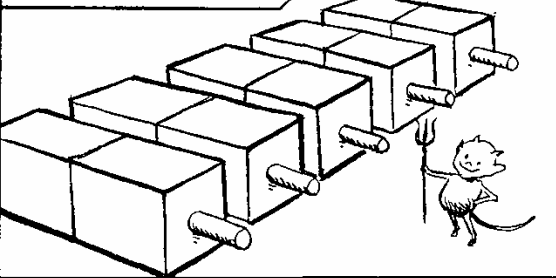
WHAT CONSUMES ENERGY IS **ERASING** THAT BIT TO RESET THE SYSTEM. **FORGETTING IS WORK!**



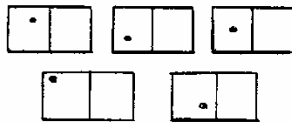
IBM INFORMATION SCIENTIST **ROLF LANDAUER** HAS COMPUTED THAT THE ENERGY NEEDED TO ERASE ONE BIT MUST EXCEED THE AVERAGE ENERGY EXTRACTED BY THE MOVING PISTON. THE 2<sup>ND</sup> LAW LIVES!



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**!!

WE BROKE THE 2<sup>ND</sup> LAW... WE BROKE THE 2<sup>ND</sup> LAW!



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..

