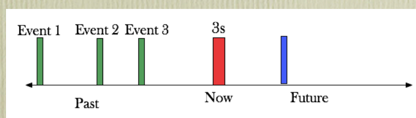
The Biggest Problem: why is there a "Now"?

We tie down past and future with events.



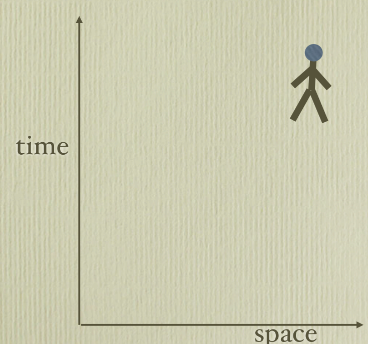
We called this the linear model

Note artists tend to be locked into the moment

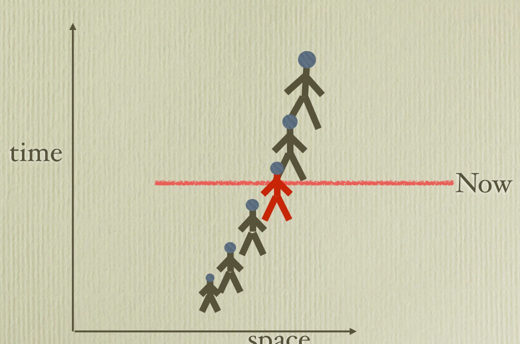
David: Napoleon Crossing the Alps

Note that we see a sequence of events

Note that we see a sequence of events

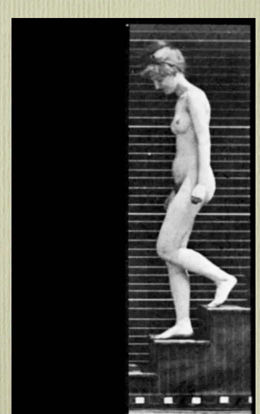


Physics is quite happy with a trajectory



i.e "now" seems to be a construct of life

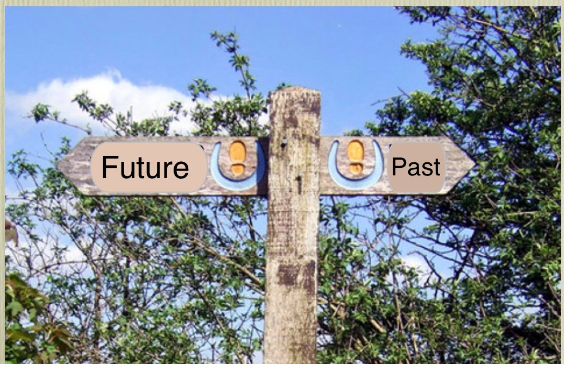
Nude descending a staircase



Maurice Duchamp (1912)

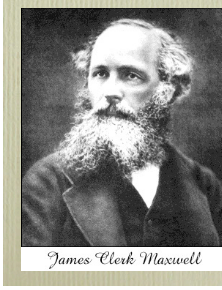
Edward Muybridge (1887)

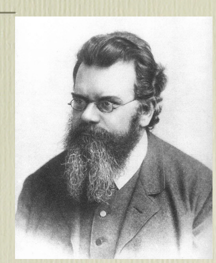
The Second Biggest Problem: why are the past and future different?



Bicycle Pumps and Rice Pudding: Time's Arrow

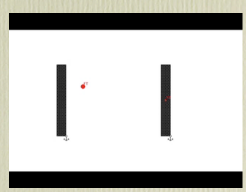
Peter Watson





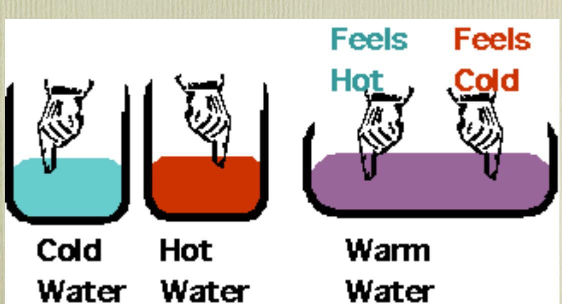
What tells us what is the direction of time?

- Is this backwards or forwards



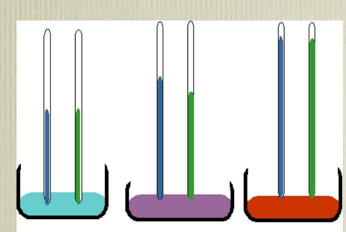
Is this?

- Temperature can be felt qualitatively, but physiological estimates are notoriously bad.



What is heat?

- So the starting question is: what is temperature?
- 0°C is water with ice floating in it
- 100°C is boiling water
- There is no guarantee that two thermometers will measure the same value in between:



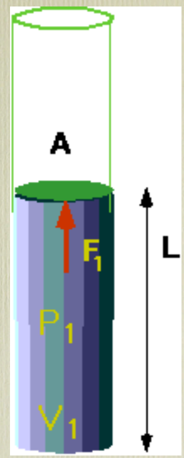
Two Views of Heat

"Macroscopic" view of heat: i.e. what quantities can we measure in a lab.

"Microscopic" view: i.e. what happens on the level of atoms and molecules.

So where is the energy in heat?

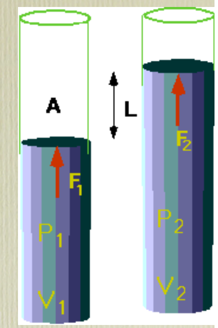
Critical experiments were done with gases:



- What happens if you pump on a bicycle pump slowly?
- Boyle found that if the pressure was varied while temp was kept constant.

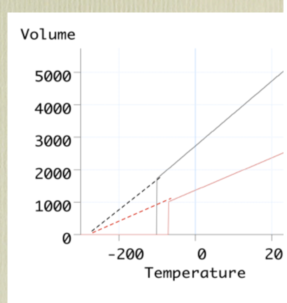
PV=const

Pressure ×Volume is constant



What happens if you heat up a balloon?

- Charles found volume increases if temperature is increased
- $V=const(T-T_o)$
- All gases have the same $T_o=-273$ C
- In practice, the gas will liquefy (e.g. N_2 at ~-200°C)
- or solidify (e.g. CO_2 at -40°C), and the relation no longer works.



- This defines absolute temp. scale or Kelvin scale: 0K =-273.16 C : the "absolute zero"
- Then $V=const\times T$
- We can combine these to give "Ideal Gas Law"
- $PV=const\times T$
- The constant depends on "amount" of gas (actually number of molecules)

Kinetic Theory

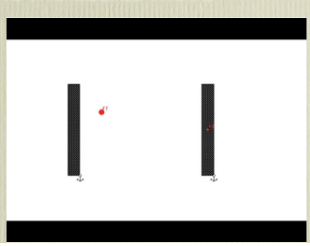
- We will look at a model first: a gas of a few atoms.

The atoms interact only as hard spheres with a rigid wall, all collisions are totally elastic.

Collisions with the wall will produce a force on the wall, which is the pressure of the gas.

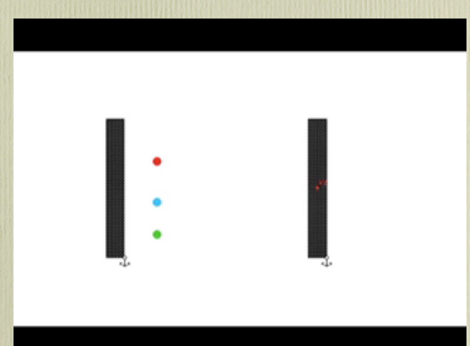
Note that collisions increase as the molecules move faster.

Start with one atom in 1-D!

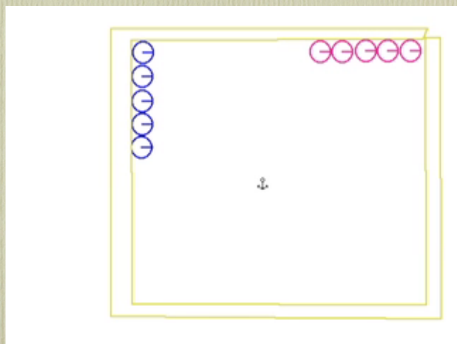


Or 3 atoms: one is moving faster

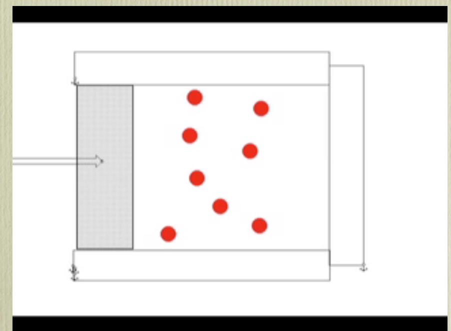
- So force (and hence pressure) is bigger



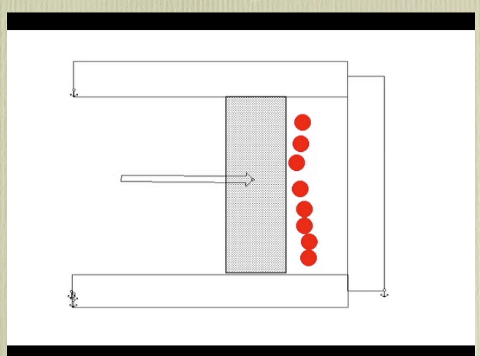
- Collisions redistribute the energy: heavy molecules move slower on average



- We can understand a number of things from the kinetic theory: e.g. how compressing a gas makes it heat up (think of a bicycle pump!)



- and how an expanding gas can do work, and the gas cools down (like an auto engine



- and this leads to .....

The First Law of Thermodynamics

Effectively: when anything happens energy is conserved.

e.g. If the piston is allowed to move, then the gas will heat or cool.

e.g suppose we paddle a canoe: mechanical energy in the paddle ⇒ motion in the water⇒ motion of the individual molecules ⇒ heat

e.g suppose we burn gasoline in a car: the heat energy in the hot gases ⇒ mechanical energy transmitted to the tires ⇒ mechanical energy (and the gas gets cold)

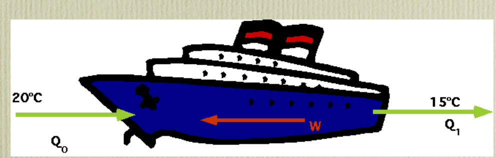
e.g suppose you eat food before running: the food energy is stored in ATP in your muscles, and ⇒ kinetic energy when you run

This is pretty obvious: **what has it got to do with time?**

The Second Law of Thermodynamics

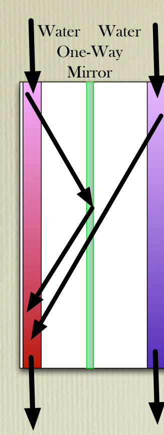
For example, why can't we have (e.g) a boat that takes in water at 20°C, extracts some heat, turns it into energy and exhausts cold water

Doesn't violate first law



How could we do it in practice?

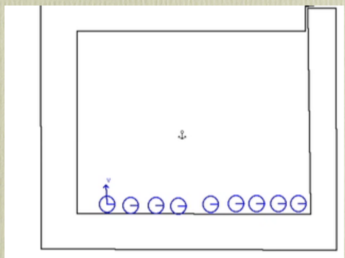
- Two pipes with water flowing with one-way mirror between them
- Radiation from the left pipe will be reflected back and reabsorbed.
- Radiation from the right pipe passes through the one-way mirror to be absorbed by the other pipe.
- Water on left heats up & boils, water on right cools down
- Can run a steam engine



Shares in the company will be available after class

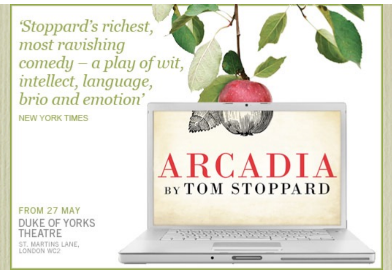
Entropy

- Essentially the relative probability of finding a particular arrangement by chance. If arrangement is improbable, we can always get work out of it.



- *A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity at the illiteracy of scientists. Once or twice I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics, the law of entropy. The response was cold: it was also negative. Yet I was asking something which is about the scientific equivalent of: 'Have you read a work of Shakespeare's?'* ***C. P. Snow***

- In order to get work out of a system, one must have a very asymmetrical system
- e.g. High pressure one side of a piston, low pressure the other side. Can this arise by chance?
- e.g. high temp. one side of a piston Can this arise by chance?
- Given 6 atoms, what is probability of finding them all one side of a room?
- Can model this via coin tossing



THOMASINA: When you stir your rice pudding, Septimus, the spoonful of jam spreads itself round making red trails like the picture of a meteor in my astronomical atlas. But if you need stir backward, the jam will not come together again. Indeed, the pudding does not notice and continues to turn pink just as before. Do you think this odd?

- Low entropy Macintosh!

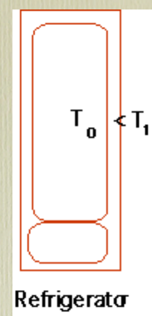
- High Entropy Macintosh!
- It is very probable that dropping a Mac will rearrange it in a more randomly ordered form!
- Dropping it again (once or one million times) is not likely to get it working again!

Another version of the 2nd Law:

Entropy tends to increase in a closed system.

Of course we can decrease entropy **locally**:
How about a fridge? Initially room and fridge at same temp., afterwards $T_0 < T_1$

- Fridge is not a closed system: must include power station.
- How about hydro-power?



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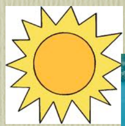


Degradation of energy:
high temp. energy (sun) ⇒ low temp. energy (earth)

Note that the words complicate things unnecessarily: easier if heat was called heat energy and entropy was called heat.

Then 2nd Law becomes

All forms of energy get converted into heat energy.

Once all the heat is at the same temperature, can get no further work.

Murphy's versions of the laws of thermodynamics

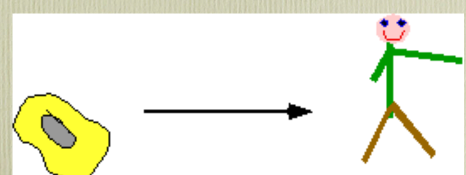
1st: You can't win
2nd: You can't break even
3rd: You can't quit the game

- Can we beat this?

2nd law and evolution

Clearly complexity of animals has increased over history of earth.
We are more ordered than amoebas (no moral judgments here!)

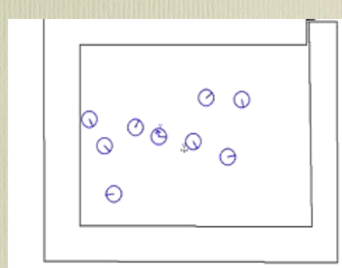
Therefore evolution contradicts 2nd law?



- Not a closed system!

Time and Entropy..

- How is tomorrow different from yesterday?
- Or better, how do you know if a movie film is being run backwards?
- The "arrow of time" is defined via an increase in entropy.
- e.g "Time's Arrow" Martin Amis



i.e how does the universe evolve, assuming that it is expands for ever?

All processes increase entropy, hence end of universe will come when entropy becomes a maximum

When temperature of everything is the same, then can do no work, hence .....nothing!

Heat Death of the Universe

"This is the way World ends,

not with a Bang, but a Whimper"

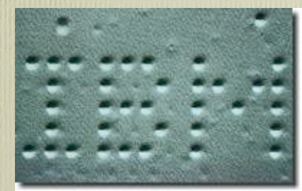
T.S. Eliot

- *Valentin: "Well, it is odd. Heat goes to cold. It's a one-way street. Your tea will end up at room temperature. What's happening to your tea is happening to everything everywhere. The sun and the stars. It'll take a while but we're all going to end up at room temperature."*
- *Stoppard, Arcadia*

- Can we beat this?

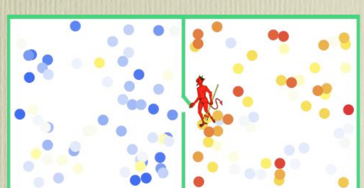
Maxwell's Demon

- Suppose we could see single atoms
- (we can, this is IBM constructed in Xenon atoms by Scanning Tunnelling Electron microscope!)



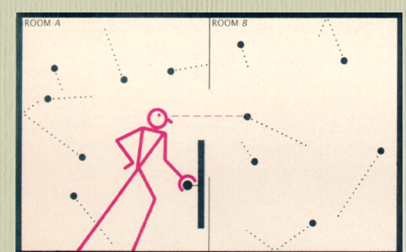
The demon can see atoms, and open a trap-door if they are hot

Allows us to separate warm into hot and cold



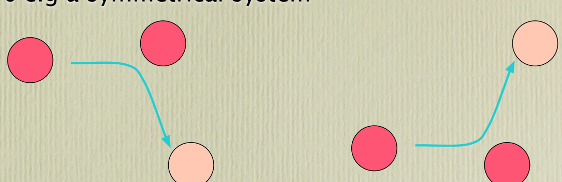
And hence to reverse time!!!!!!!!!!!!!

Violates Second law?

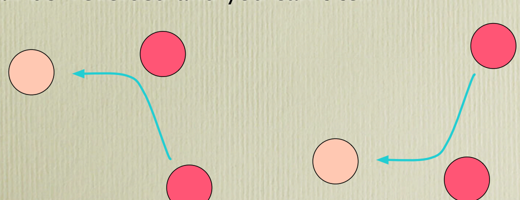


No: the demon has to use energy to look at atoms: extra energy heats up gas and nullifies effect!

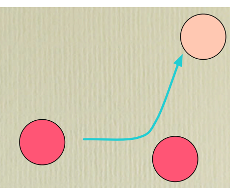
- Entropy seems to require many objects. Can we define the direction of time with one or two
- e.g a symmetrical system



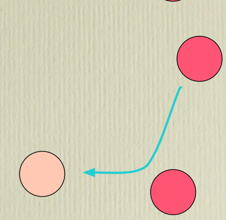
can be reversed and you can't tell



- But suppose the system is only left-handed?



- Then when you time-reverse it, it becomes right-handed!



i.e. you can tell which way time flows if things have a "handness" (proper word is "parity")
so London becomes "nodnoL"!
and neutrinos become anti-neutrinos!

- Can we beat the second law?

- Freeman Dyson: Time without end: Physics and biology in an open universe

- Will look at this in last lecture

- Now we need to improve our understanding of the link between <u>space and time</u>