Rosen ASPFS
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Causes and effects in quantum systems

Rutherford experiment

Scattering – if sharply peaked momentum distrib in incident beam is part of the C then positions of individual particles are indeterminant, so not in C

E = the "scattered" wave fcn, from which probabilities and differential cross sections can be calculated.

Classical Interpretation

C = statistical properties of incident beam and target material (since no way in practice to know position, velocity, orientation of all incident particles) – (we don't have ~~Pauli Exclusion Princ~~ Heisenberg uncertainty Princ)

E = statistical properties of scattered particles.

Quantum interpretation

C = Incident wave fcn and scattering potential

E = scattered wave fcn

Vacuum state of Quantum Theory $S(C) \leq S(E)$

It is often regarded as a violation of the Symmetry Princ but really we must include vacuum state in C

This reduces the Symm of C and then E is not less Symmetrical than C.

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Ch 5.2 ~~Spontaneous~~ Symmetry Breaking

a priori, the Symm Princ must hold $S(C) \leq S(E)$

but there appear to be physical systems where $S(C) > S(E)$

(we have lost symm) $f: C \to E$ or maybe $C: M \to E$

E only inherits a broken symm of C.

Birkhoff p.38

For example G.D. Birkhoff hydrodynamic Symm paradoxes

The resolution is that the C is not the complete C, and when we take into account the total cause, C has much less Symm.

For example, small random fluxuations in physical systems.

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(2)

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So C may only possess an approx symm. What can be said about E in that case

No reason approx Symm in C to produce Symm in E.

We can regard the real C as an exact symm (C^* ⊕ perturbation)

3 cases may arrise

Liapunov Stability (1) f(C) → E damps out the perturbation

Neutral Stability (2) f(C) → E E has same degree of Asymm as C

instability (3) E has less Symm than C (pert is amplified)

Case 1 Stability against perturbs

solar system — all planets lie approx in a plane

Let C be planets now in plane — Reflection Symm

Comets, non spherical planets etc are perturbations

E = planets in the future, still approx in plane

Case 2 Neutral Stability

DC circuit in §4.4 p.124 C 2 fold reflection Symm

But real resistors, capacitors etc would never be perfectly identical so the symm is broken

E is the currents. If C is perturbed slightly from symm, then E is only perturbed slightly from Symm

Case 3 Instability of Symm

Solar Sys on long timescales from origin

C = Dust cloud, very Symm (approx).

E = State today, much less symm

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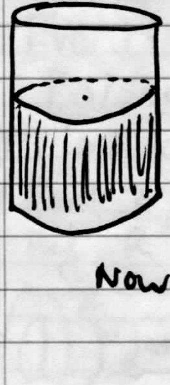

Water at rest in a container — isotropic, homogeneous that is the symm

Tap the side of the container — introduces an asymmetry of pressure waves, but they damp out and symm returns.

On the other hand, if we carefully lower the temperature with no instabilities, temp can go below freezing pt — supercooling.

Now if we tap side, ice crystals immediately form — Symm broken.

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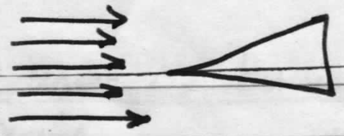
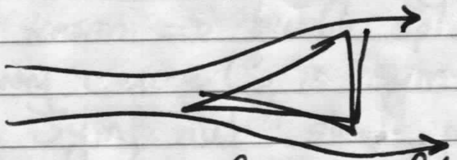
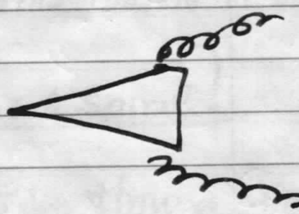
air flow past a wedge







- Low speed, laminar flow, centerline reflection symm is preserved.
- Higher speed, flow becomes turbulent vortex shedding, sometimes on the top, sometimes on the bottom.. Not symm anymore

BUT if we took many photos at random times we would see the same number of vortices on top and bottom

That is the Symm. Total collection of photos shows reflection symm between top and bot.

G. Birkhoff Hydrodynamics (symm paradoxes)

(p. 4) (c) Symmetric causes produce effects with the same symmetry

(p. 39) Nearly Symm causes need not produce nearly symm effects
A Symm problem need have no stable symmetric solution

This is the proposed answer to the following paradoxes:

(p. 37) Flow in straight tubes – Symm Hypothesis (c) is fulfilled if Reynolds number $R < 1700$ But for $R > 10^4$ we observe neither temporal or spatial symm.

With extreme care, we can polish the inlet and the tube walls and make sure in inflow is laminar – then we may preserve sym up to $R = 400$[illegible]

▷ The Symm hypoth is still fulfilled stochastically. (leads to study stochastic PDEs)

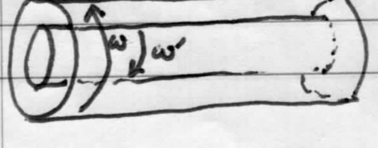
(p. 38) For $R > 1700$ Symm seems to break down and so does Law of Least Action

Poiseuille flow involves much less energy than turbulent flow.

(1) Flow in pipes of non-circular cross section

Reynolds Small R: parallel flow, Least Action holds

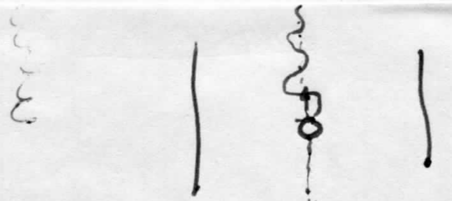
Big R: Flow is turb, not even statistically parallel

(2) 

Flow between Long coaxial cylinders rotating opp dirs

At small ω, ω' Couette flow

High Reynolds R: Asymmetrical flow, not turb



(p. 39) (3) <u>small air bubble, rising in still water under its buoyancy</u>

Surf tension ⇒ bubble spherical, or very nearly

Every cause C is sym about vertical axis thru centroid of bubble

By Sym, bub should rise vertically in line

<u>BUT</u> for $R > 50$ bub <u>wobbles in a vertical spiral!</u>

(4) Wake behind a circular cylinder pulled broadside thru a stream

$50 < R < 500$

Rosen also discusses this or a variation

Harder to pull a stick thru water at rest than it is to hold the stick at rest in a flowing stream — presumably because there is always some turbulence in flowing stream

(not sure what page this was on)