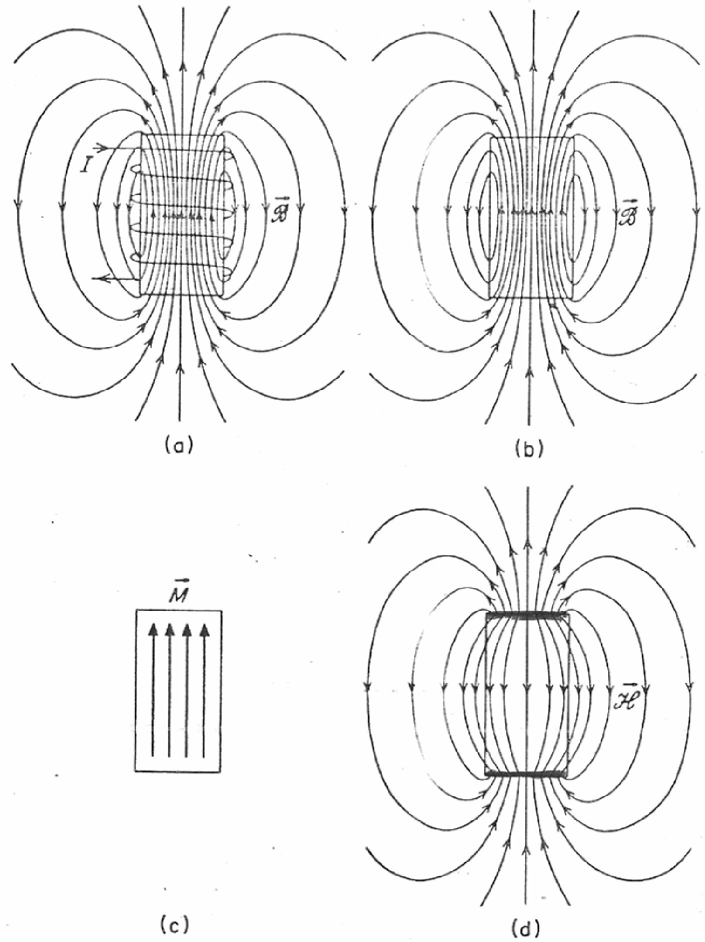
A problem with the Math of Magnetism

- **Magnetization M is really a discontinuous density function (a number density) but it is treated as a continuous function.**
- **This is OK for determining the fields *external* to a magnet.**
- **This is not OK for determining the fields *internal* to a magnet**
- **The wrong use of M hides the actual magnetic energy stored in the inter-atomic space.**
- **That unrecognised stored energy is not trivial**
- **Access to that energy is obtainable by various means**

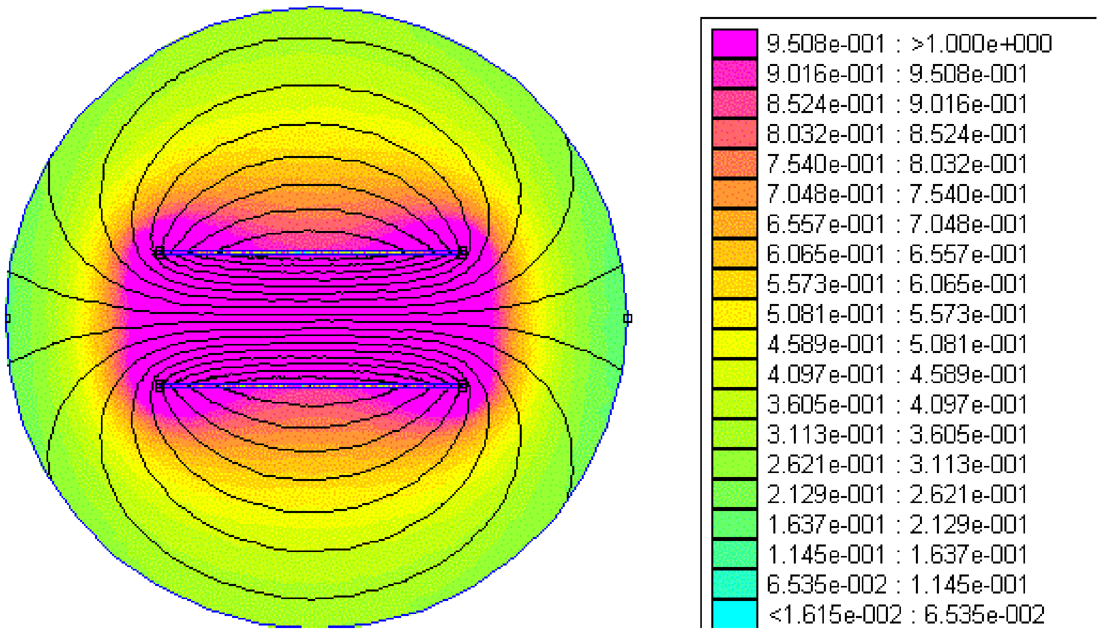
- The historical manner in which magnetism developed has created a science which has some serious disconnects in its formulation, never more so than in the physics of ferromagnetic materials. Even though modern scientists know that the magnetization comes from arrays of discrete atomic dipoles, where in that micro-universe the separation between atoms is huge compared to their size, that inter-atomic space and the magnetic fields therein are generally ignored. Scientists use a term called *magnetization* (usually denoted **M**), which is a volume-density of a "substance" called *dipole-moment*, and pretend that "substance" is smoothly spread through all space within the material. It is like the difference between a barrel of apples and a barrel of apple puree, for mathematical convenience we pretend that the dipoles can be turned into dipole puree.
- This is OK for determining the fields external to the magnet, but it is *not* OK for the fields internal to the magnet.
- That inconsistency, the filling of inter-atomic space with that imaginary substance, prohibits the calculation of the actual magnetic fields there and so continues to hide the magnetic energy stored in that space and its vital connection to the atomic dipoles, the *Quantum Dynamos®* that Nature has supplied.
- For permanent magnets those inter-atomic fields are not trivial, and the stored energy has a density close to the magnet's maximum BH_{max} energy product.
- There are various means for extracting and using some of that hidden energy.

The Classical View

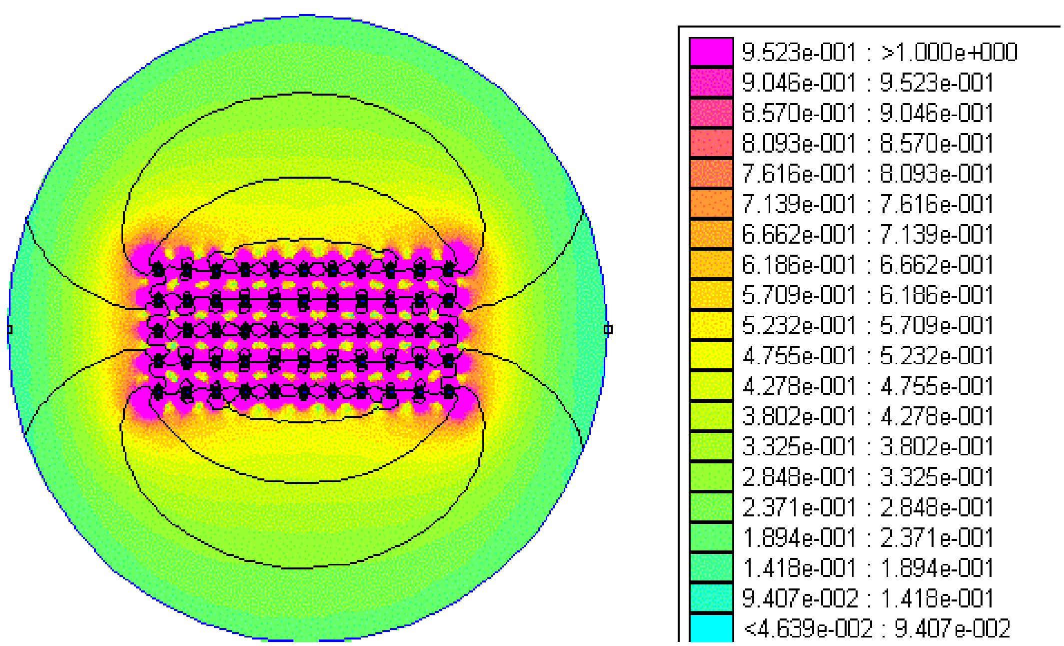


5-19 (a) A plot of $\mathscr{B}$ for an air-core solenoid; (b) an equivalent magnet; (c) the magnetization; (d) a plot of $\mathscr{H}$ (after Pugh and Pugh, *Principles of Electricity and Magnetism*, Addison-Wesley Publishing Co., Reading, Mass.)

This is an image taken from "Electromagnetic Theory for Engineers and Scientists" showing (a) a plot of flux density **B** for an *air-cored* solenoid and (b) the same for an equivalent permanent magnet. The external fields are identical and thus it is acceptable to model the magnet by its solenoid equivalent, but whereas in a real solenoid we have to supply the current (and energy), in the permanent magnet the effective current circulation comes from atomic dipoles (electron spins or orbital motion obeying quantum rules), i.e. the magnetic energy is supplied from the quantum inner world. Also shown are (c) the magnetization **M** within the magnet and (d) a plot of the induction field **H** for the magnet. The thick lines in (d) represent the imaginary North and South poles. I say imaginary because magnetic monopoles do not exist. Note the **H** lines emanate radially from these imaginary poles, and within the magnet the **H** field direction in (d) (downwards) is opposite to the **B** field direction in (b) (upwards). There the reversed **H** (relative to **B**) creates difficulties in establishing the magnetic energy stored within the magnet. That reversed **H** is as fictional as the poles, and its presence is a direct result of the magnetization **M** as a sort of dipole puree spread throughout inter-atomic space. That imaginary puree prohibits free-space where **B** and **H** can coexist as they do in air or vacuum



This is a FEMM simulation for the **B** field lines through a solenoid with colour added to represent field density. Compare this to the **B** field for an array of small current loops.



The discontinuous nature is readily observable, and it may be noted that everywhere, both inside and outside the array, **B** and **H** fields are contiguous and related by $\mathbf{B}=\mu_0\mathbf{H}$. Reverse **H** does not occur. Although in the real magnet the volume number-density of atomic dipoles is enormous (like 10^{28} per cubic meter) the dipoles themselves are tiny, the inter-atomic space contains magnetic energy stored in the field. That stored energy-density is not trivial, it has a value close to the BH_{max} energy product for the magnet.

Access to Internal Energy

- **Induced Circular Electric Fields**
- **Conduction Electrons**
- **Magnetoelasiticity**

Access to internal energy of ferromagnetic materials can be gained by induced electric fields, by conduction electrons within the material and by mechanical stress.

- With a man-made circular current (current through a coil) energy can be taken from or given to the current source if there is an induced voltage, the induction coming from a circular *electric* field which applies force to the conduction electrons in the wire. That also applies to the ferromagnetic atomic dipoles, the circular electric field tries to accelerate or decelerate the electron orbital speed or its spin. Although an applied magnetic field is required for the creation of circular electric loops, the electric field is proportional to the rate of change of the applied field, hence the electric field can be present while the applied magnetic field passes through zero. It will be appreciated that supplying a circular electric field in phase with the magnetization represents a 90 degree phase shift between the magnetization and the external field. In electromagnetic machines anomalous effects often show up when there is excessive phase shift, i.e. when the machine is used outside of its usual operating envelope, and there is increasing evidence that some machines exhibit anomalous power gains.
- Of particular interest are ferromagnetic materials that are electrically conductive, where the itinerant conduction electrons traverse that inter-atomic space. In that inner world, not only are those electrons influenced by the static field (cyclotron effect), but they are also driven by the RF magnetic fields coming from Larmor precessions of nearby atomic dipoles. Thus it can be expected that conduction electrons within ferro-magnetic material can be pumped by the *Quantum Dynamos*® to exhibit anomalous effects, and there are many examples where anomalies have occurred only to be spurned by a sceptical scientific community. The work of Hans Coler lead to two devices, in one case using conduction through a permanent magnet and in the other case conduction through the core of an electromagnet. Harold Aspden reports anomalous effects from eddy currents on transformer cores. And patent archives have many examples of machines exhibiting anomalous effects using moving magnets where eddy currents flow within the magnets.
- What happens when you squeeze a magnet? You won't get much change in **B** ($\delta\mathbf{B}$), which is the easiest thing to look for (change in **B** induces voltage into a coil), but you will get a significant change in **H** (because $\delta\mathbf{H}=\delta\mathbf{B}/\mu_0$ which is more easily remembered as $\delta\mathbf{H} \approx 800{,}000\delta\mathbf{B}$), and that needs special equipment to discover. Exploiting $\delta\mathbf{H}$ is an area ripe for investigation.