MAJOR QUESTION:

If we measure a force-field around an object which contains the sources of the field, what can we find out about these sources ?

- "force-field" here means action-at-a-distance, that is, through a vacuum.
- Let the object have the shape of a sphere, to start with.

Different force-fields, in order of complexity :

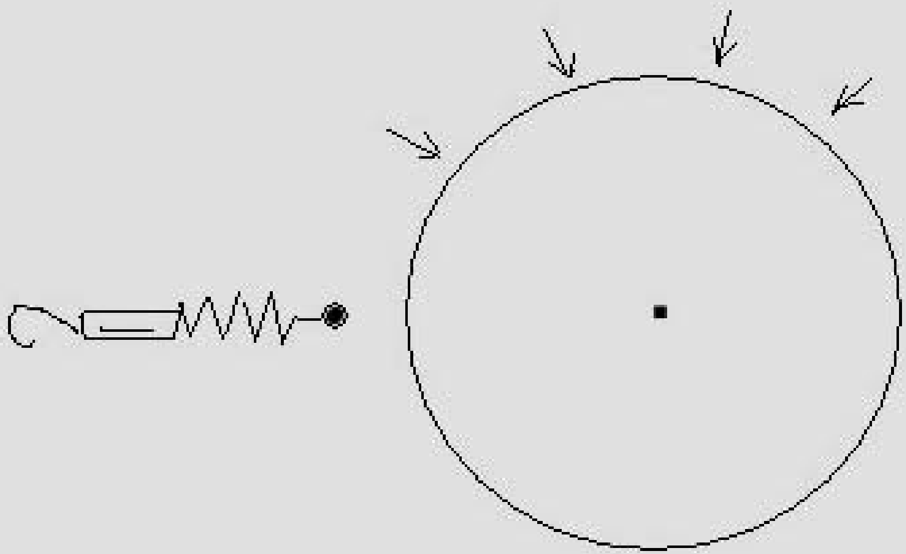
- Gravitational
- Electrostatic
- Magnetic
- Nuclear (two types)

In the following, we will discuss the first three -- not nuclear.

We will do the following :

For each of the three forces, we will put the simplest source in the sphere. We will look at the field it makes around the sphere. Then we will pretend to measure this field, assuming we ***didn't know*** the internal source which made this field. From this measurement, we try to find out as much as we can about the source.

Gravitational Force

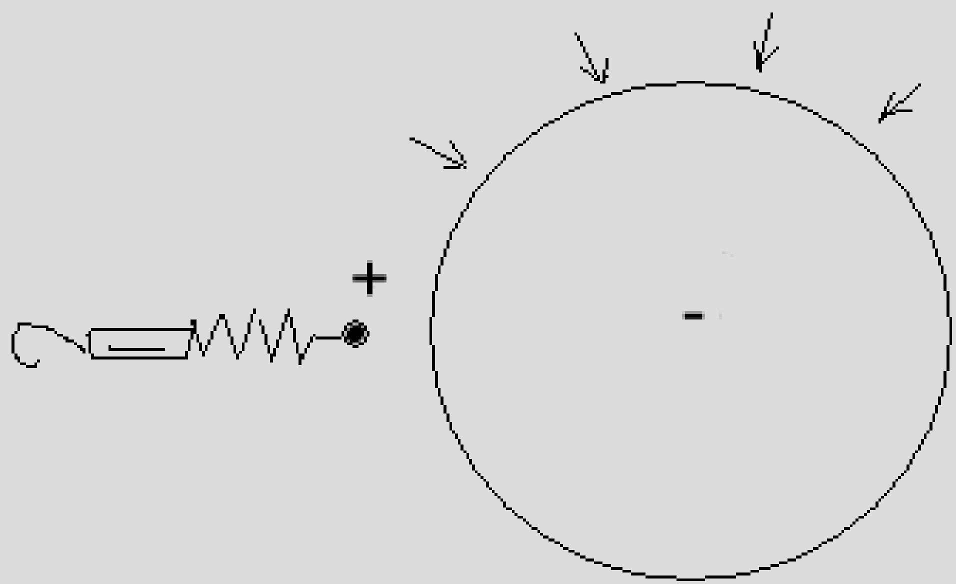


Simplest :

A point source
at the center
makes a uniform
field around
the sphere

Of interest: If we didnt know there was a point source
at the center, we could determine the total
mass and that it was symmetric about the
center, but not its radius.

Electrostatic Force

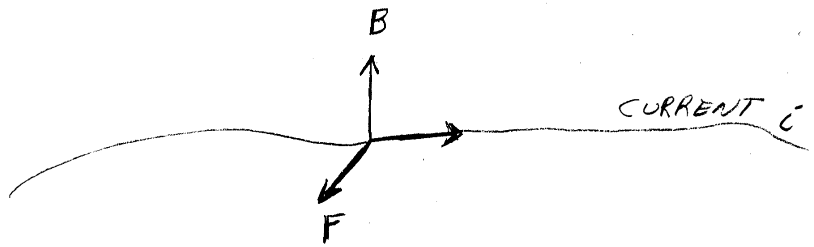


Simplest :

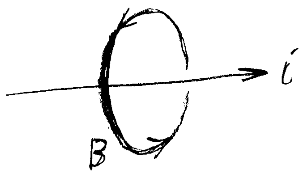
A point charge at the center makes a uniform field around the sphere

Of interest: If we didnt know there was a point source at the center, we could determine the total charge and that it was symmetric about the center, but not its radius.

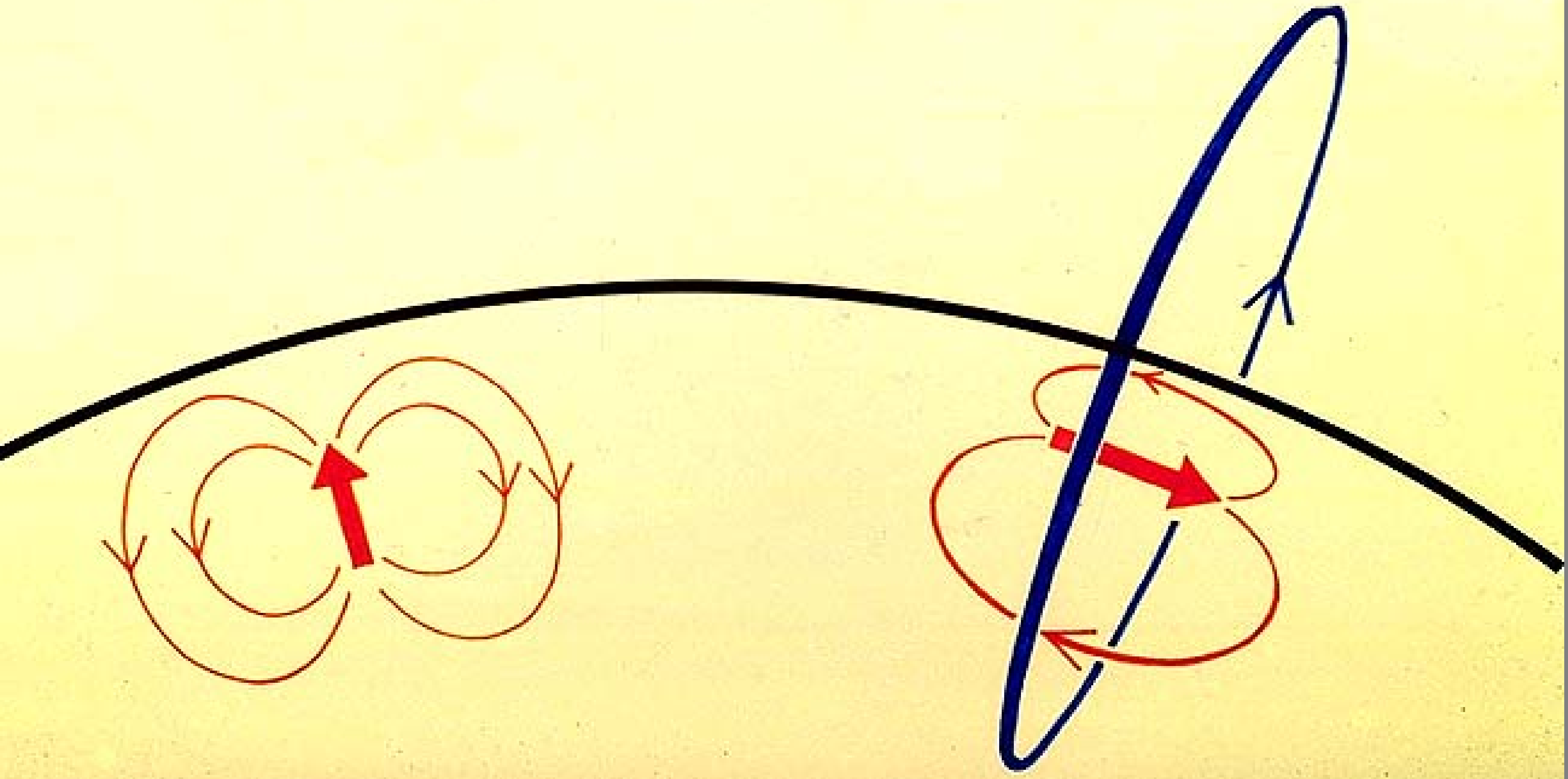
What is the definition of a magnetic field ?



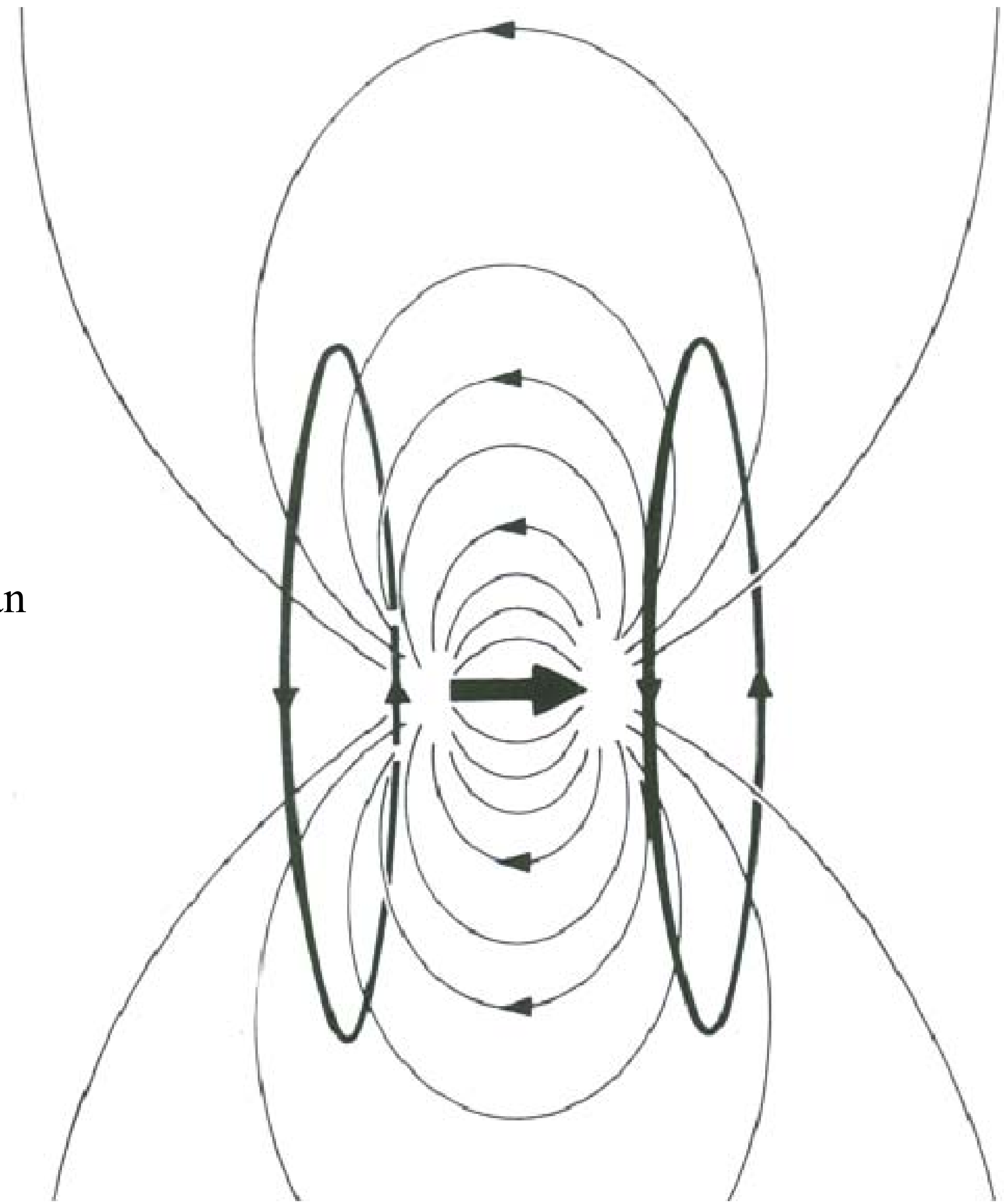
What is the source of a magnetic field ?

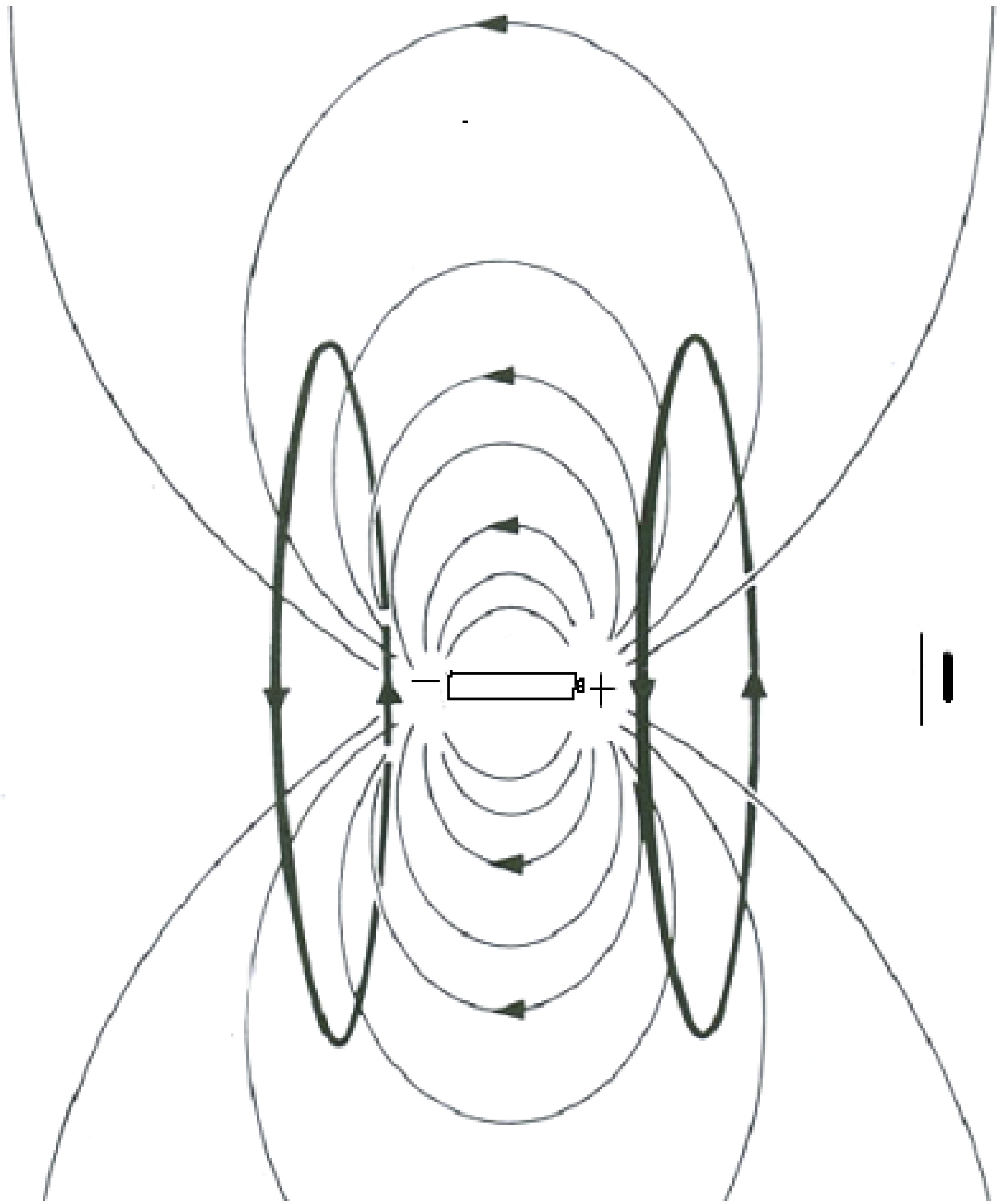


If we now have a conducting sphere, and make currents in the sphere, the simplest source is a current dipole. Consider two orientations: radial and tangential.



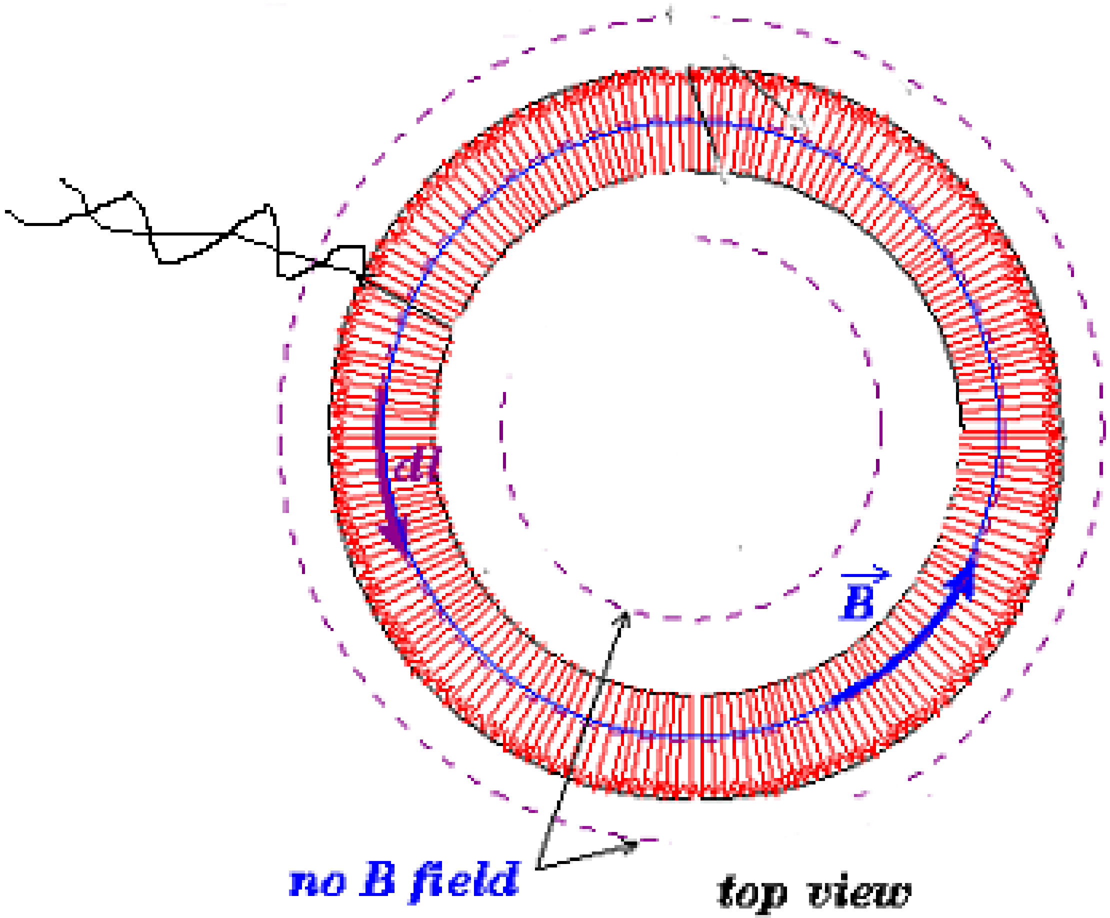
A current dipole in an infinite conductor



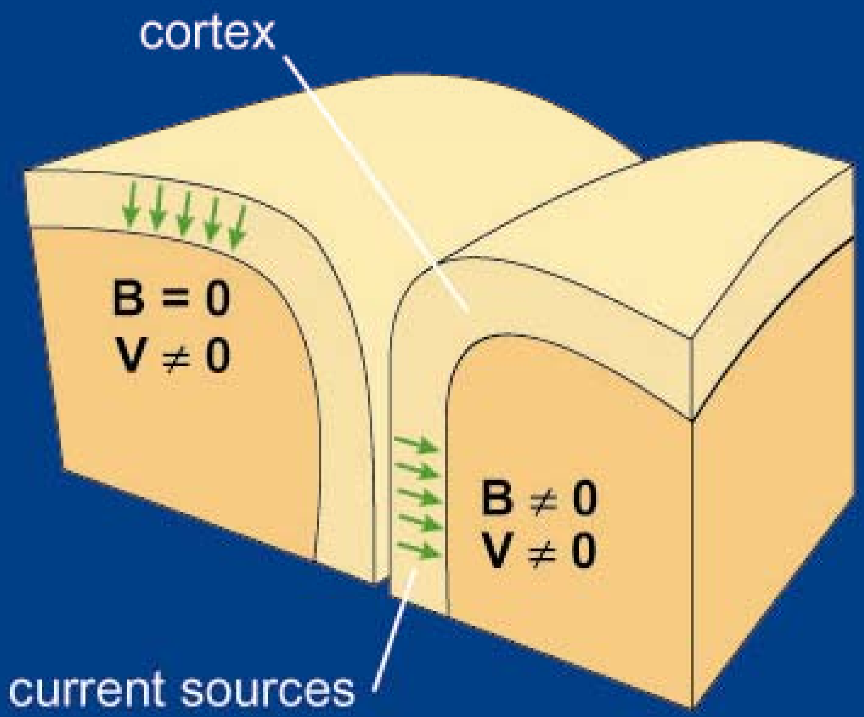


Think of a current dipole as a tiny AAA battery; that's all it is.   Symbol at right.

A toroid produces zero external magnetic field. If we think of the radial dipole as producing an infinite series of toroids, around it, we can see why it produces zero external field over the sphere. Its because of thesymmetry…



Primary currents on the cortex



MEG sees mainly fissural activity.

EEG is sensitive to currents in the convexial cortex as well.

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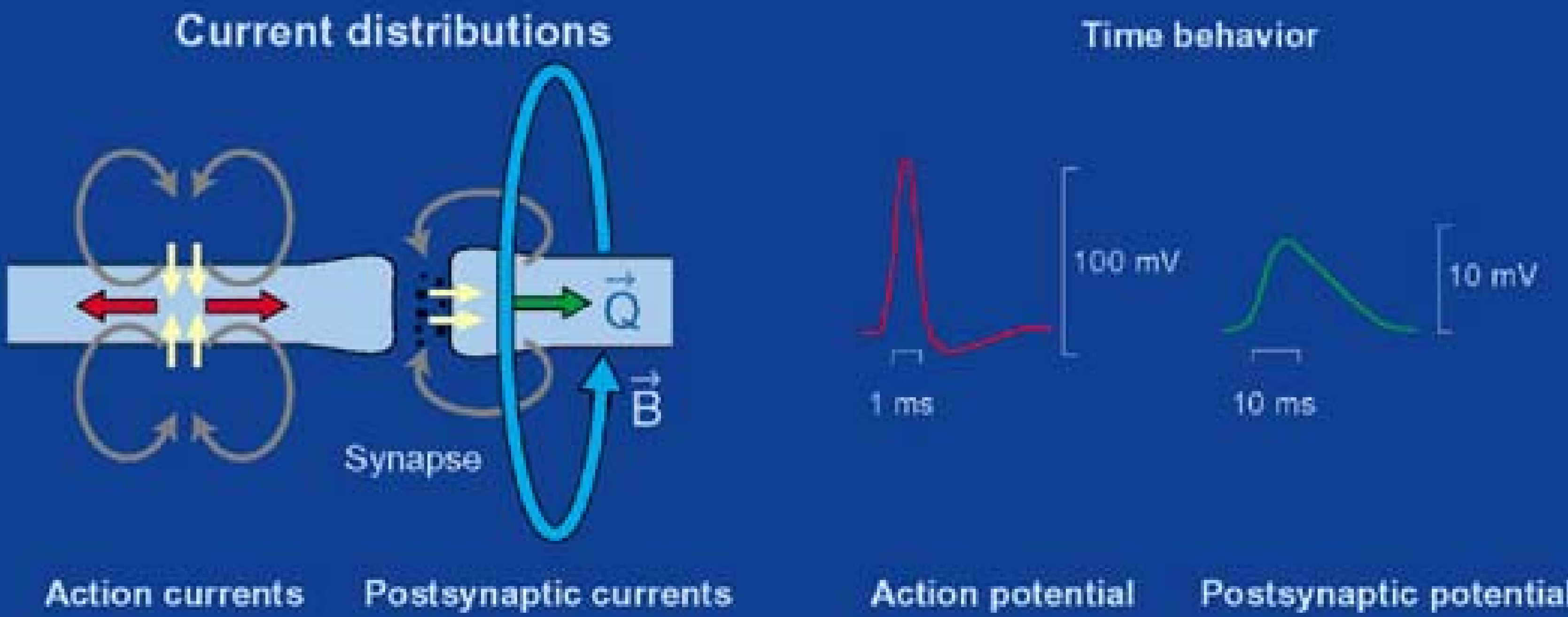
Consequence of zero external magnetic field from a radial dipole in a conducting sphere

Source of MEG and EEG signals

Action potentials



Postsynaptic currents dominate:

- Unidirectional current
- Temporal summation

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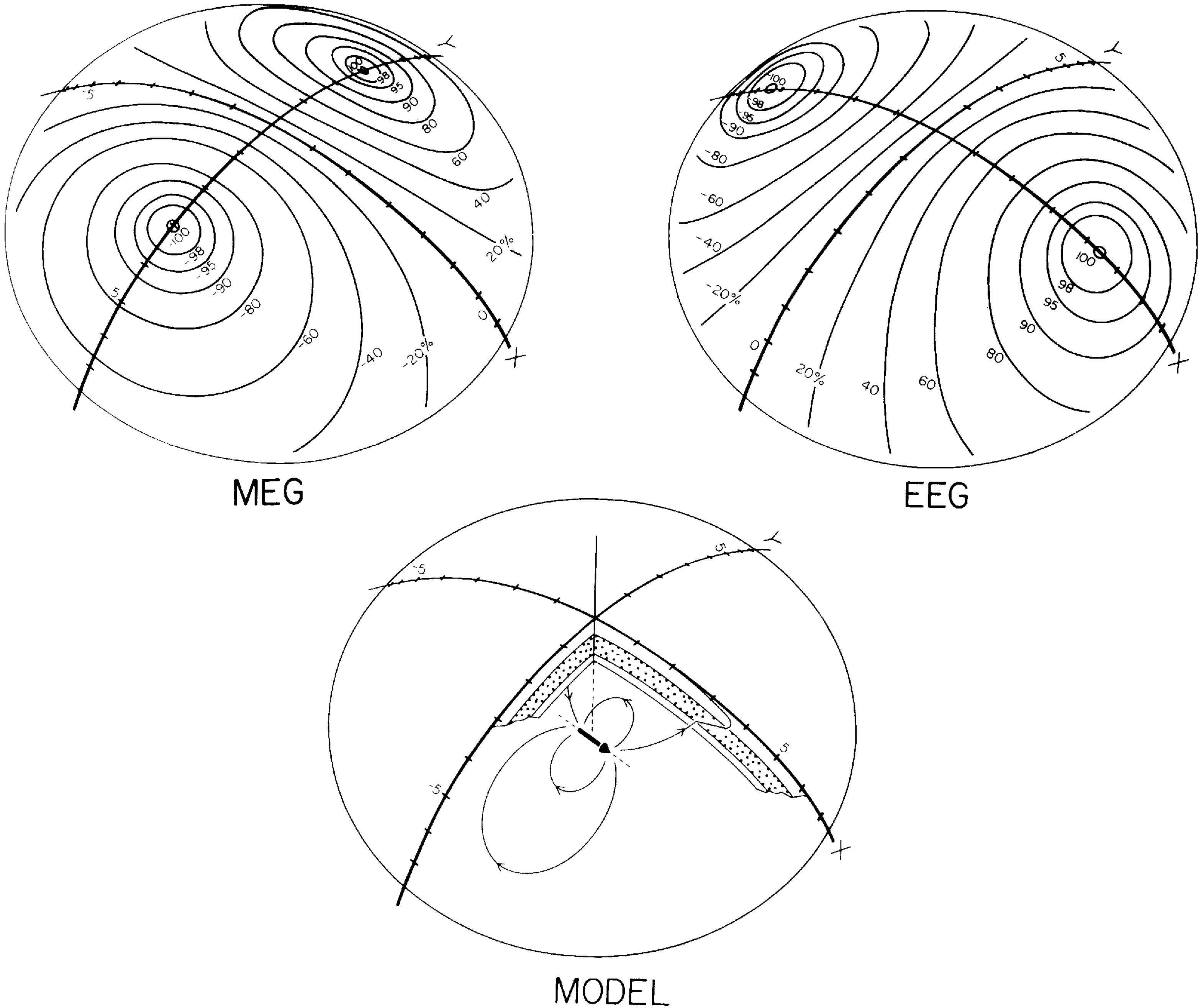
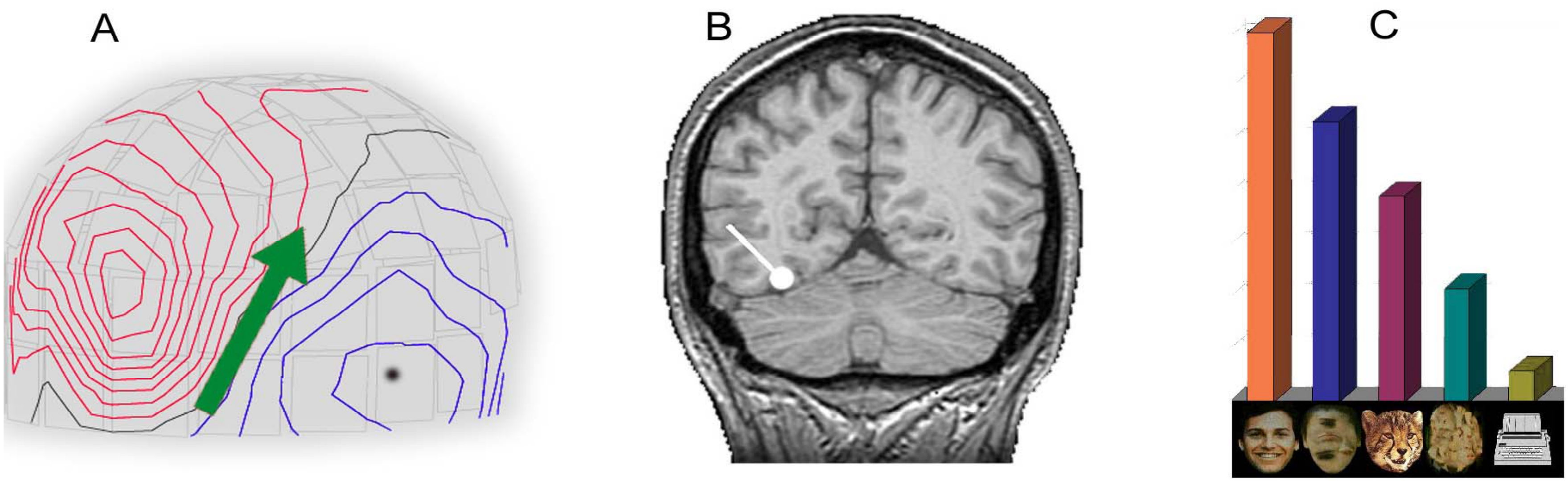


Normal component of magnetic field, and surface potential, due to a tangential dipole in a sphe

The current dipole (green) which produces the measured dipole-like MEG magnetometer pattern over the head (red and blue), from a visual experiment by Halgren's group.

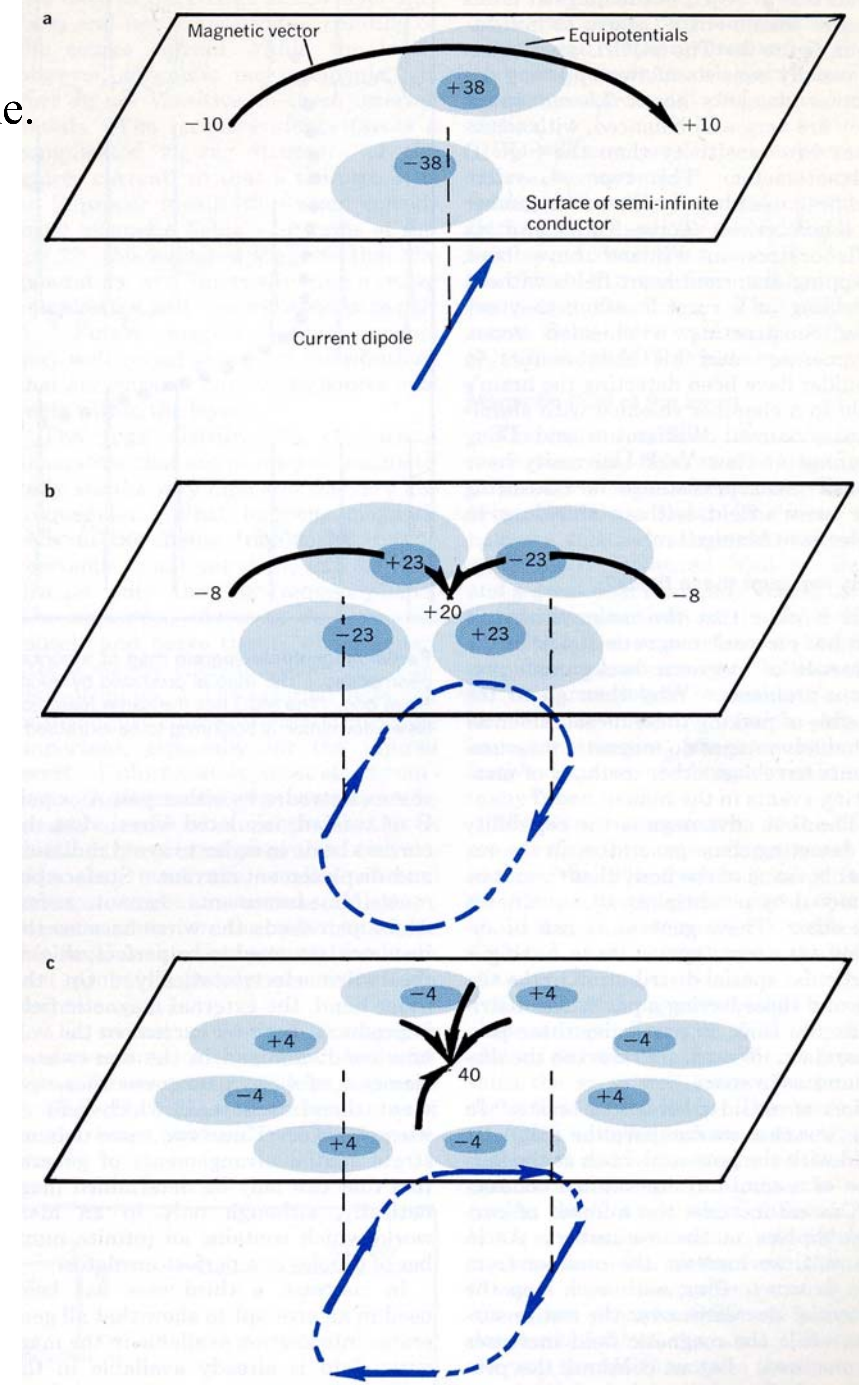


Actually, any number of complex configurations of dipoles can produce similar MEG patterns. The single dipole is THE SIMPLEST !

The MEG was able to distinguish which of these two models produces the somatosensory N20 pattern over the head. Both models give about the same EEG pattern. From MIT.

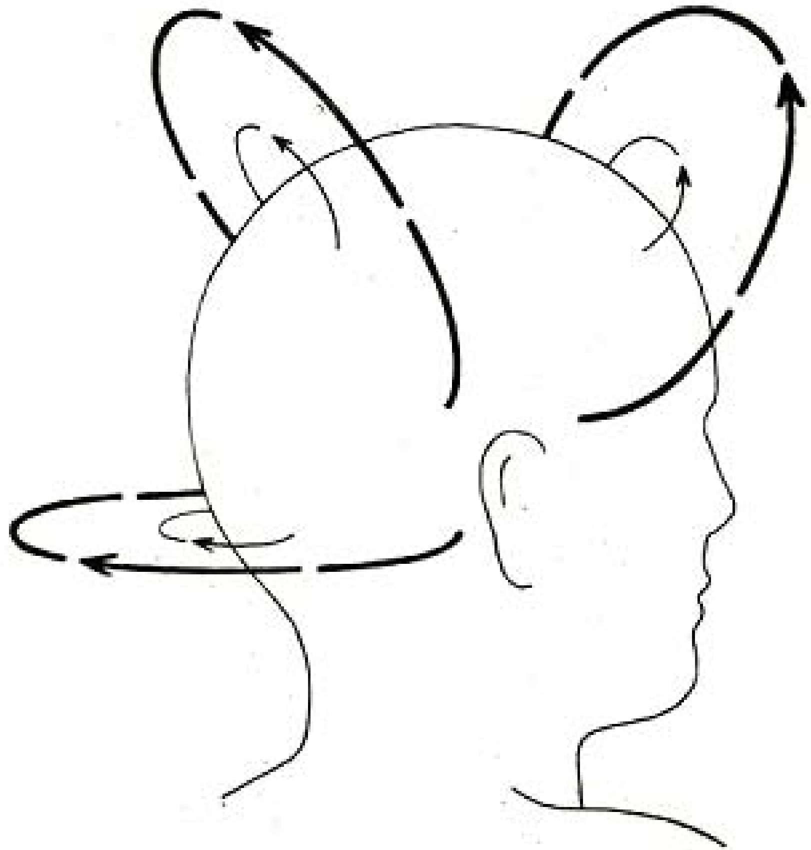
One, two, and four dipoles in semi-infinite volume. The numbers on the surface are the computed potentials (blue circles) and vertical magnetic values. The central magnetic value increases with the number of dipoles, while the potentials decrease. Thus, the MEG signal gets stronger, while the EEG gets weaker.

In the limit, approaching an infinite number of dipoles "around the ring", the EEG vanishes. This is called a magnetic dipole. There is no evidence, so far, of such sources in the human brain. If present, these sources would be truly new information, not obtainable with the EEG.

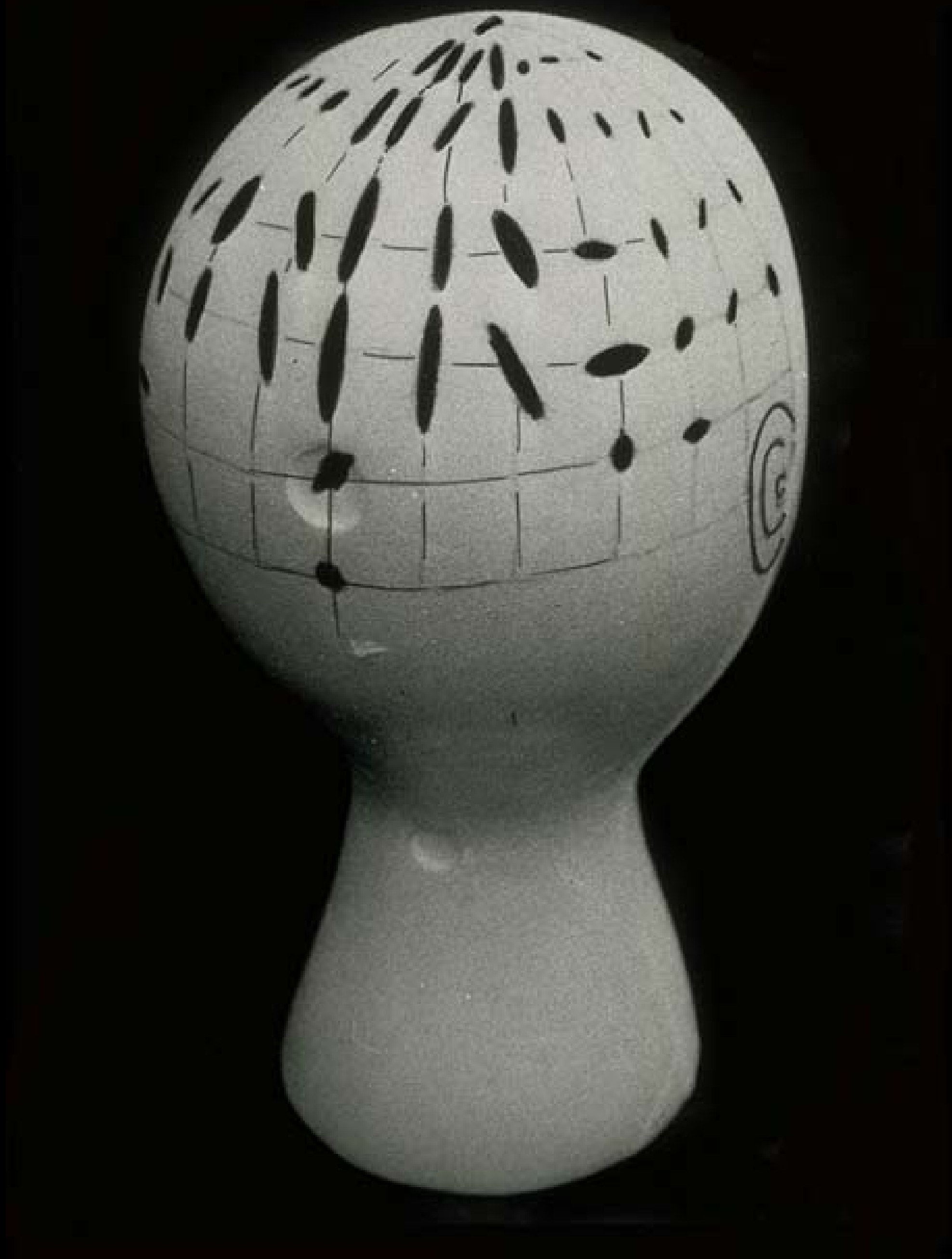


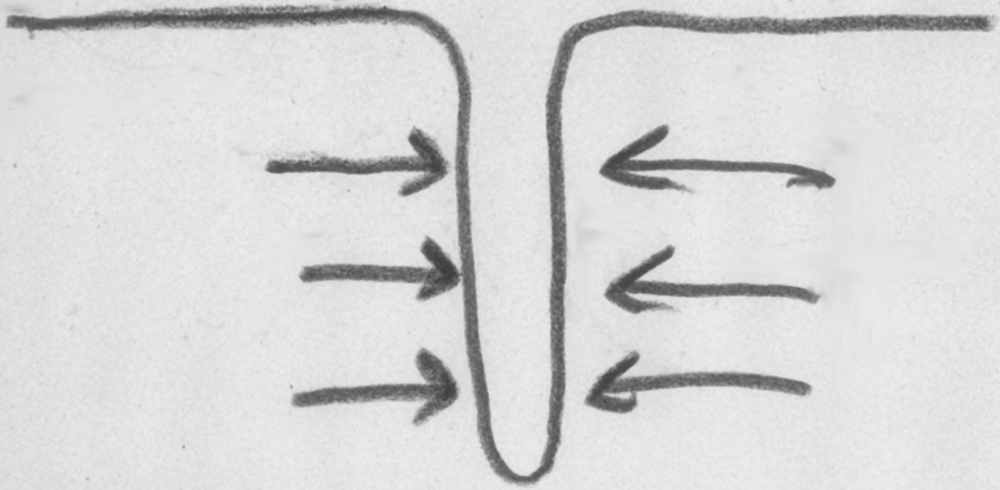
An early exprimental MEG puzzle

An instantaneous picture of the alpha-rhythm magnetic field over the head of a subject with bilateral EEG symmetry.

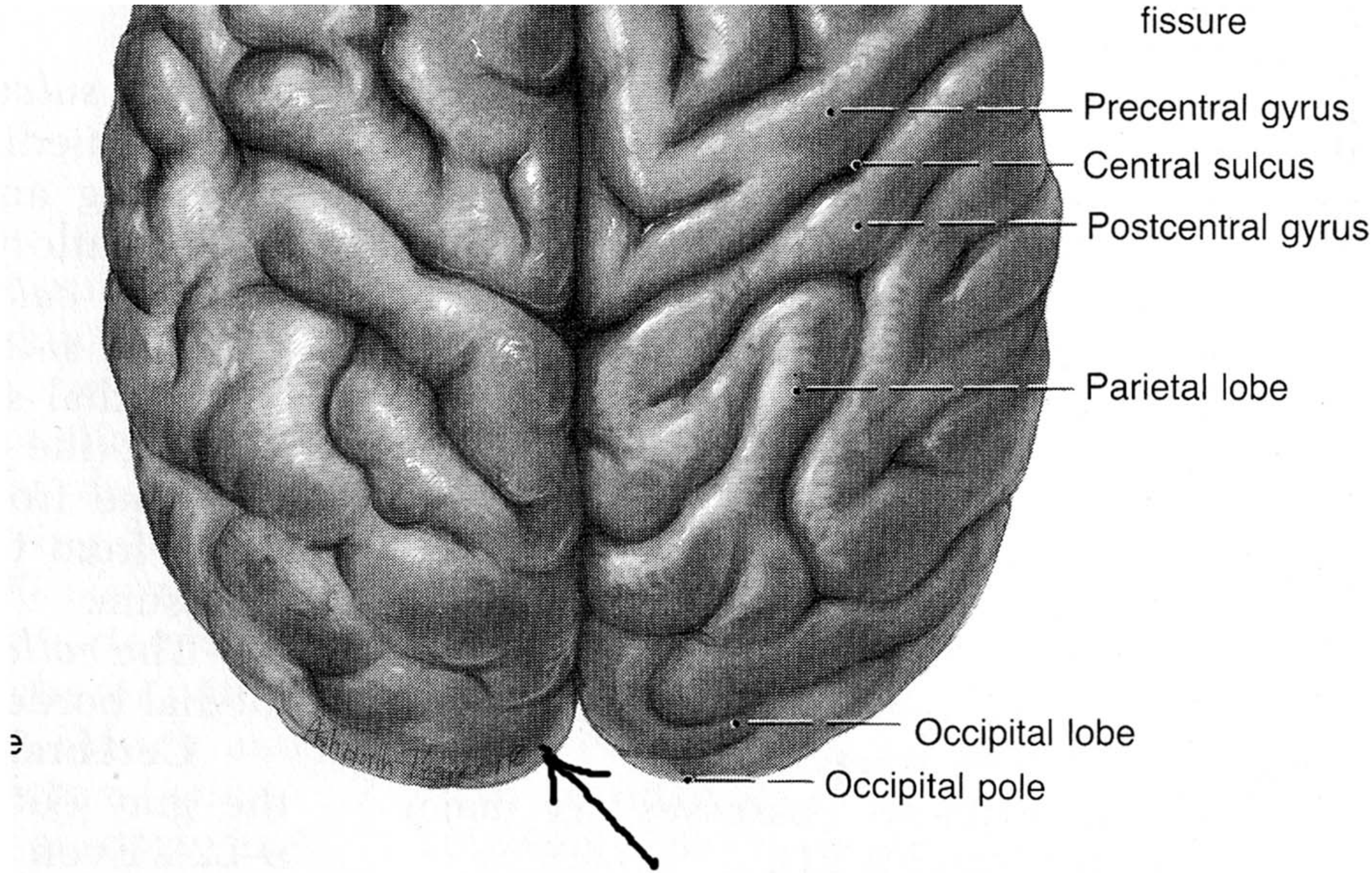


A time-summation of dipole oscillations due to planar gradiometer measurements of the same type of alpha subject. What causes the high degree of polarization ?

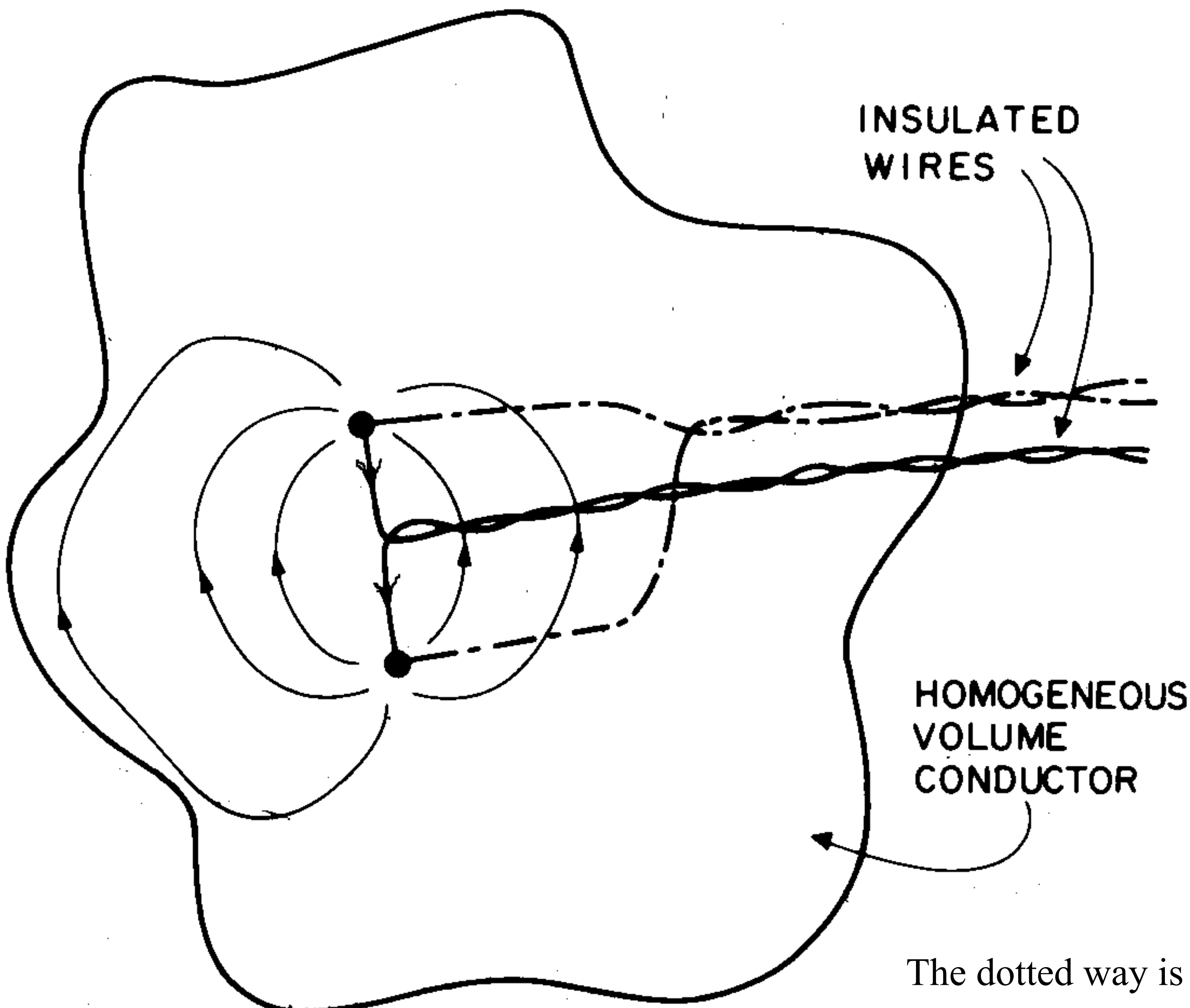




Two-dimensional fissures cannot give the polarized alpha-rhythm patterns in bilaterally-symmetric cases

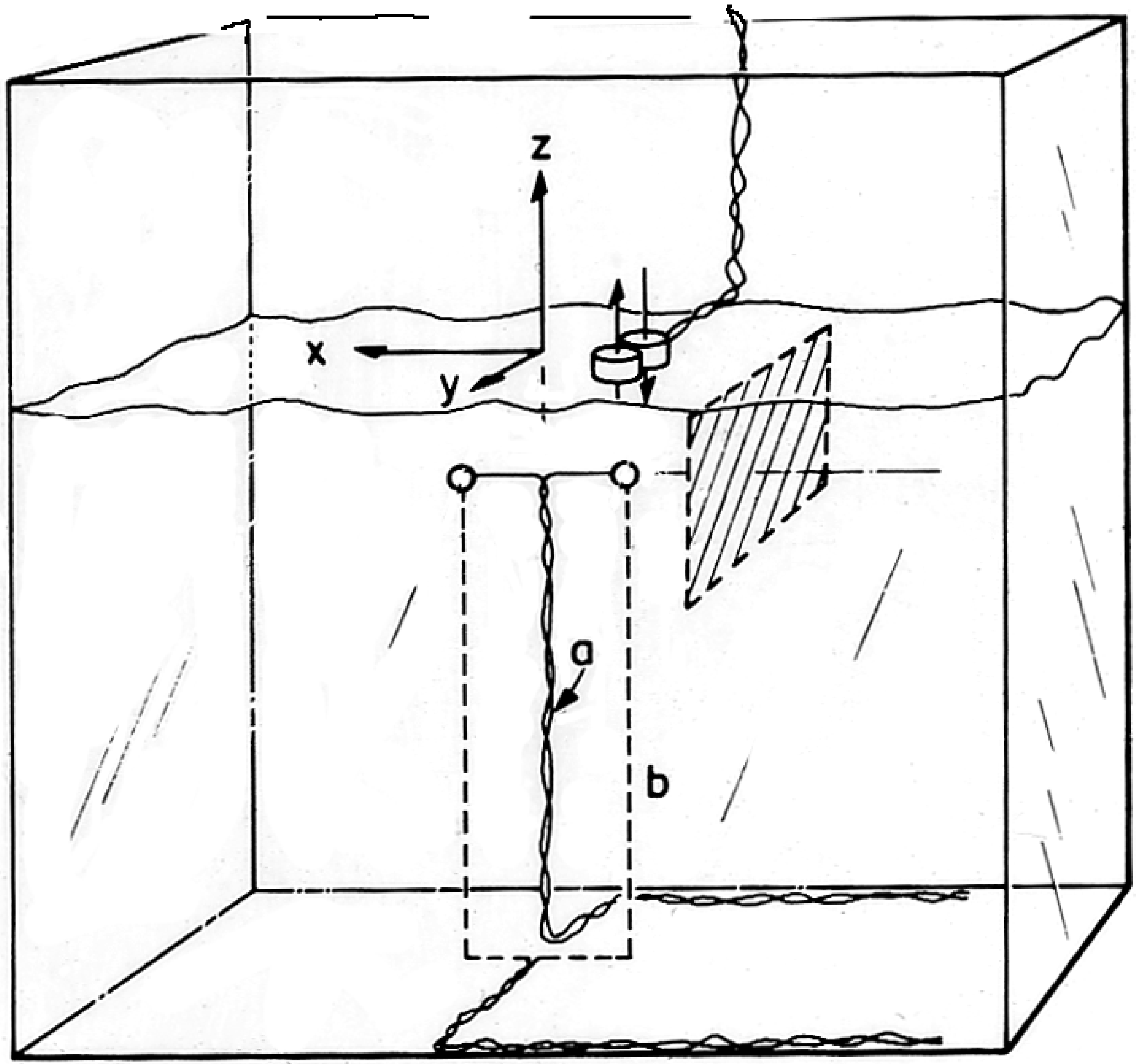


Dipoles on this slope contribute to actual tangential dipoles; MEG alpha reflects these slopes.



The dotted way is wrong.

Two different ways to make an experimental current dipole in an arbitrary volume conductor.



Early experimental arrangement at MIT for studying dipole physics

Implanted electrodes in an epileptic subject, used to create experimental current dipoles

The use of dipoles in the concept of "lead fields".
Upper figure: sensitivity pattern for
a planar gradiometer. Lower: sensitivity
pattern for bipolar EEG electrodes.
Some similarity is seen between
the two patterns.