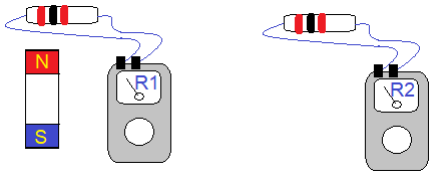
# Electromagnetism

## GMR Sensors

If you take a common resistor (let's say 2kΩ) that we use in the electric circuits lab and put it in a magnetic field, the value of its resistance doesn't change much. But do not take my word for it, go to the lab and check. The change in resistance with magnetic field is known as magnetoresistance and as mentioned (and hopefully confirmed by you) it is normally an imperceptible effect.




In spite of that, in the 19th century it was found that certain materials showed a small change in their resistance when the magnetic field was parallel or perpendicular to the current. This small effect is known as magnetic resistance anisotropy. It is not practical to build a sensors based on this effect.

The state of the art changed in 1988 when a group of researchers working in Albert Fert's team in France demonstrated that a structure formed by two magnetic conductors sandwiching a non-magnetic one had a change in resistance by a factor of 2 when the magnetizations were parallel compared to antiparallel. See the paper in *Physical Review Letters*.

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**Giant Magnetoresistance of (001)Fe/(001)Cr Magnetic Superlattices**

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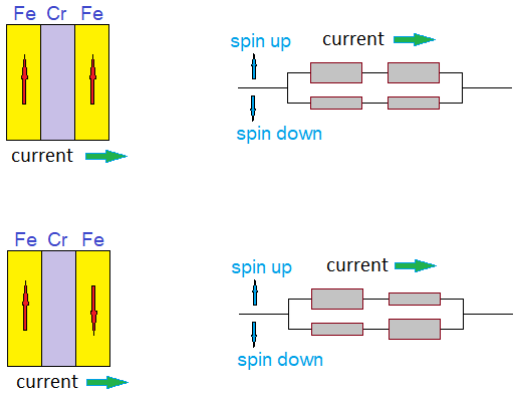
Later, other research group in Germany saw the effect independently and published it in 1989.

The figure below shows the structures schematically with an equivalent circuit that illustrates how they behave. Can you tell which one has more resistance?




This opened the possibility of creating very small sensors using one of the magnetic conductors as a probe. The application of these GMR sensors to the reading heads in hard disks allowed their miniaturization and price reduction in the 1990s. Incidentally, this played a role in the inflection point at Apple whose first iPod could carry one thousand songs in your pocket as the legendary Steve Jobs used to say.