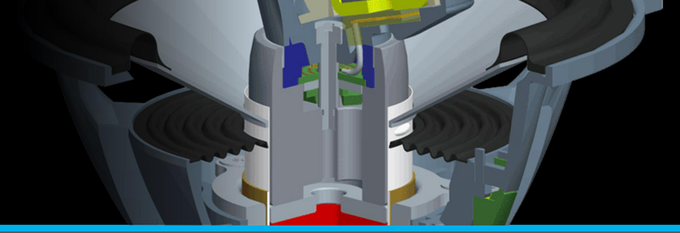
Neodymium Magnet in a Speaker



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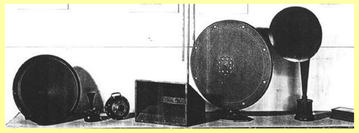
Introduction

Speakers are composed of a cone attached to an electromagnet, and a permanent magnet. Variations in electric charge induce changes in the electromagnetic field at the electromagnet and move the cone relative to the permanent magnet, producing soundwaves. A key factor in the function of the speaker, and the topic of discussion for this poster, is that the permanent magnet needs to produce a strong and consistent magnetic field to interact with the variable field of the electromagnet.

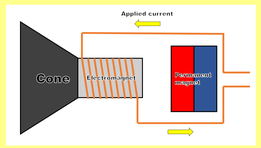
The most common permanent magnet among speakers is an alloy, a mixture of metals that is more stable and resistant to corrosion than the constituent metals. Both iron and neodymium have magnetic moments on every atom, because they have several unpaired electrons with the same quantum spin in their outermost electron shells. These magnetic moments on individual atoms can combine parallel to each other among large groups of atoms to form magnetic domains. These domains contain very many atoms which all contribute to make a strong magnetic force which will remain even in the absence of an applied magnetic field, this is a property known as ferromagnetism. The strong and consistent magnetic field produced by this alloy can interact with the variable field of the electromagnet in a predictable manner which can be used to produce specific sounds with the cone.

History of Speaker



- The earliest loudspeakers were invented in the mid-1800s.
- Early speakers didn't utilize permanent magnets like modern speakers and instead used dual electromagnets due to their excessive cost and weight.
- Speakers using these permanent magnets, first invented in 1930 by Jensen, became more common after world war II when lightweight alnico magnets became widely available.

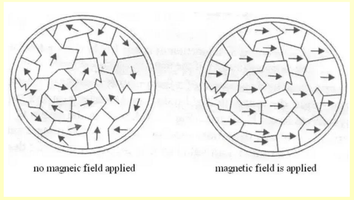
How a Speaker works



- The speaker produces sound when the electromagnet is enabled or disabled which will cause it and the permanent magnet to attract or repel each other.
- The back-and-forth motion of electromagnet is controlled entirely by the electric current applied to the electromagnet.
- The more quickly the current changes, the faster the cone moves and the higher the pitch.
- More current will increase the electromagnetic force applied to the electromagnet, which will deform the cone more and produce more sound.

Magnetism

- Magnetic fields are produced by the motion of electrically charged particles such as electrons, which have an angular momentum, also known as spin.
- Small magnetic fields are cancelled out by dipole with paired spin up and spin down electrons.
- Unpaired electrons gives the whole atom a dipole to form a domain, and many of these domains can combine together to form a magnet.

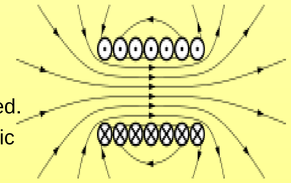


Measurements of Magnetism

- Remanence is the amount of magnetization that a magnet has when there is no outside field being applied to it.
- Coercivity is the amount of applied field that is required to scramble the direction of the domains and effectively demagnetize the magnet.
- Field strength density is the amount of magnetic force produced per unit volume of the magnet.

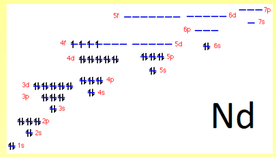
Electromagnets

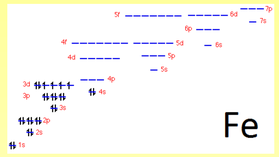
- Electromagnets are magnets which produce their magnetic field using electric current
- When electric current is allowed to flow through the wire, a magnetic force is produced.
- When there is no current, there is no magnetic field produced.

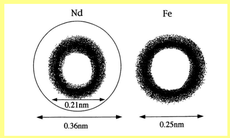


Comparison with Fe and Nd elements

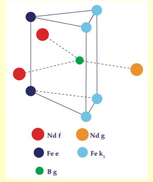
	Iron	Neodymium	$Nd_2Fe_{14}B$
Types of metal	Transition	Rare-earth	Alloy
Types of Magnet	Weak ferromagnet	Antiferromagnet	Rare-earth
Structure	Body-centered cubic	Double-hexagonal close-packed	Tetragonal crystalline
Electron configuration	$[Ar]4s^23d^6$	$[Xe]6s^24f^4$	N/A
Outermost Shell	3d	6s	N/A
Delocalized electrons	No	Yes	N/A
Remanence (B_r)/T	2.2	1.0-1.3	1.0-1.4
Coercivity (H_{ci})/kA/m	0.080	875-1990	750-2000
Curie temperature (Tc)/ºC	770	320	310-400



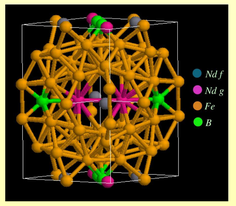


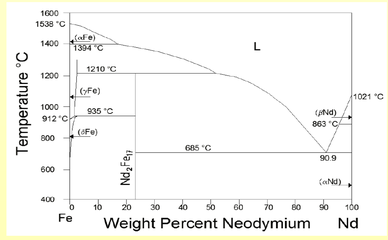


Structure of NdFeB



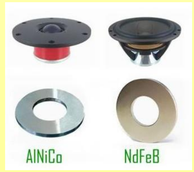
- There are 4 units $Nd_2Fe_{14}B$ per unit cell
- Iron atoms are fully connected as hexagonal nets
- Boron addition enhances the coercivity and remanence
- The size and shape of the magnet change the magnetization and demagnetization





Comparison with AlNiCo Magnet

	NdFeB magnet	AlNiCo magnet
Composition (& by weight)	64.2-68.5% Fe, 29-32% Nd, 1.0-1.2% B, 0.8-1.2% Dy, 0.5-1% Nb, 0.2-0.4% Al	13-26% Ni, 6-13% Al, 2-6% Cu, 0-42% Co, 0-9% Ti, 0-3% Nb, Fe (balance)
Density (D)/g/cc	7.5	6.9-7.3
Electrical Conductivity (r)/μΩ cm	150	45-70
Remanence (B_r)/T	1.0-1.4	0.6-1.4
Coercivity (H_{ci})/kA/m	750-2000	275
Maximal energy product (BH_{max})/kJ/m³	200-440	10-88
Curie temperature (Tc)/ºC	310	810-860
Advantages	○ Resistance against demagnetization ○ Small-size magnet	○ Strong magnetic field ○ Highest Curie temperature ○ Resistance against corrosion
Disadvantages	○ Vulnerable to corrosion	○ Brittle ○ Low resistance against demagnetization



Conclusion

Speaker produces sound by the interaction of a permanent magnet and electromagnet. Neodymium magnet is commonly used permanent magnet in speakers because of high magnetization and demagnetization, and small-size.

Reference/Acknowledges

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