Actuators in Electro- and Magnetostatics

Outline

Lorentz Force Law
MEMs Devices
Homopolar Motor
Speakers
Homopolar Generator

TRUE or FALSE?

1. **Tangential electric field is always continuous at a surface.** ____

2. **Tangential magnetic field is always continuous at a surface.** ____

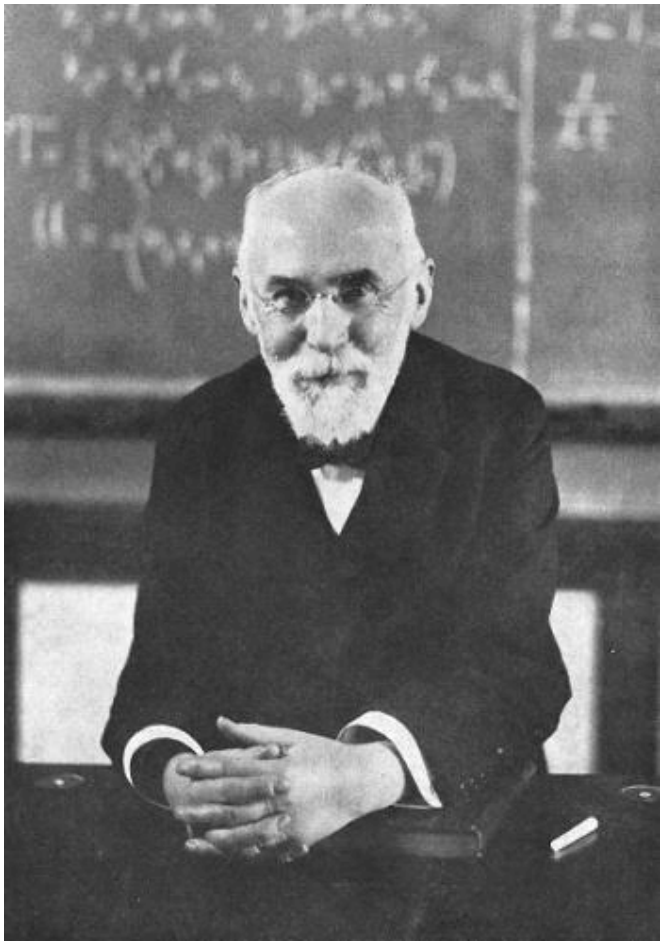
3. **An electric generator, or dynamo, is created by running a motor is reverse, i.e. hooking up the power source with the opposite polarity.** ____

Lorentz Force Law (1892)

$$\overline{f} = q(\overline{E} + \overline{v} \times \mu_o \overline{H})$$

Replaced Ampere's force law, widely used in the 1800s

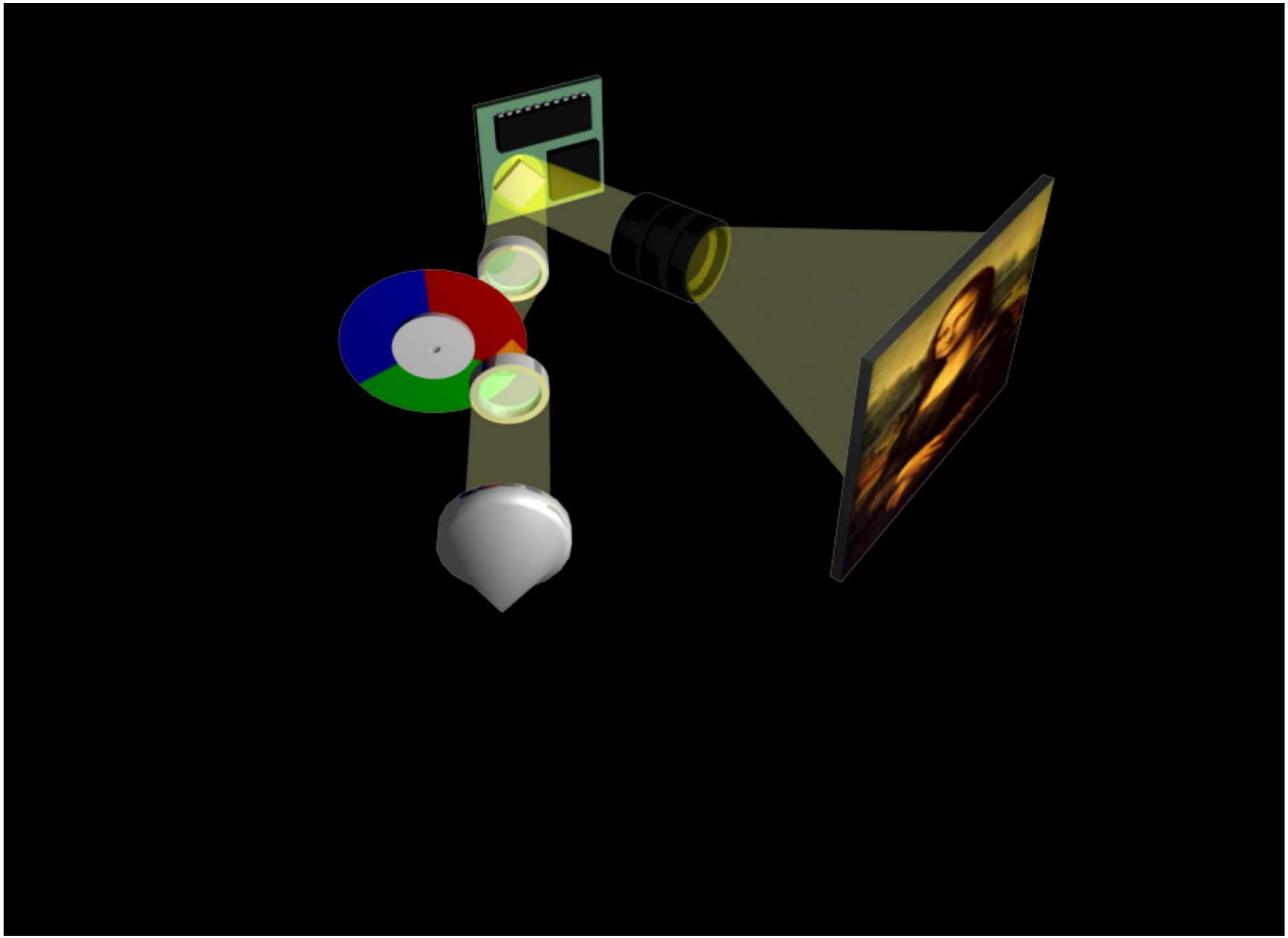
v x B term had been known earlier; was published by Maxwell in 1861



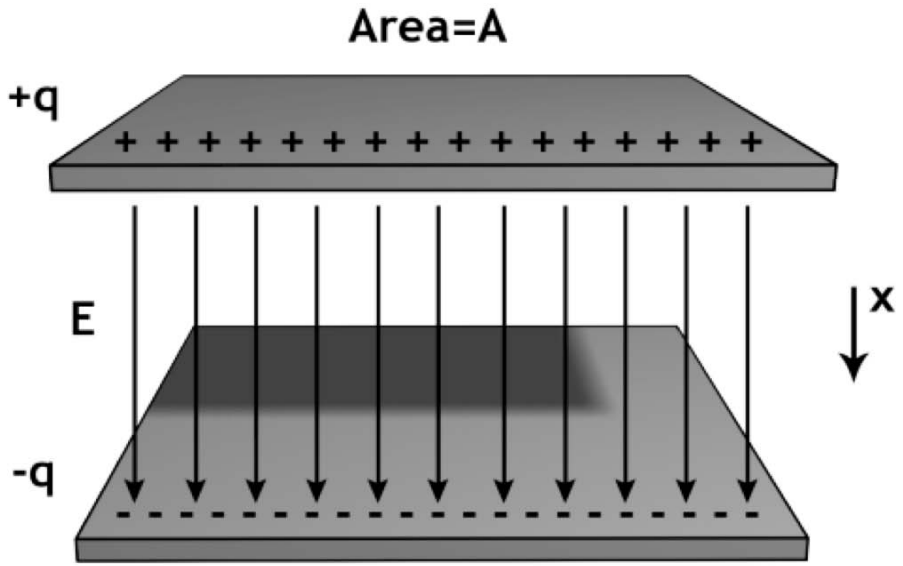
Hendrik Lorentz

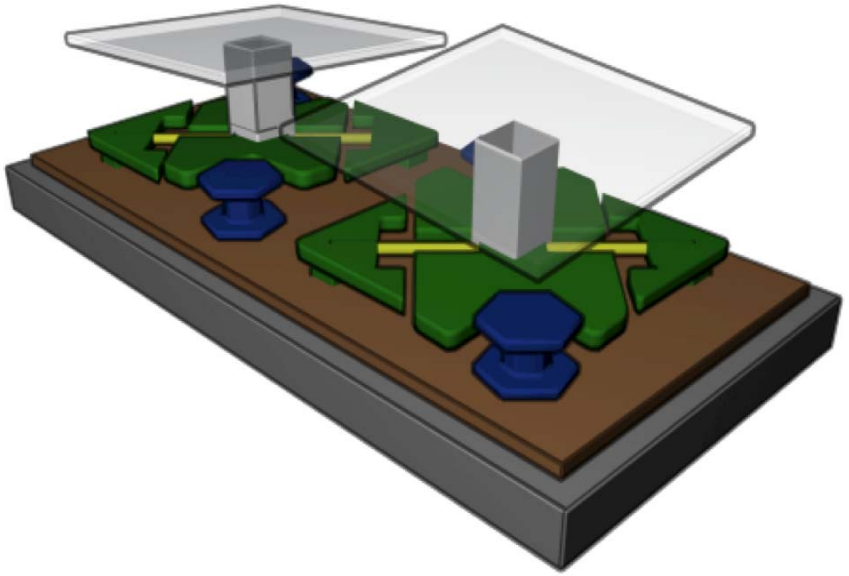
Note that this law does not explain forces on dielectrics or magnetically permeable materials. Most common actuators employ these forces.

Digital Light Processing



Normal Force between Two Charged Plates





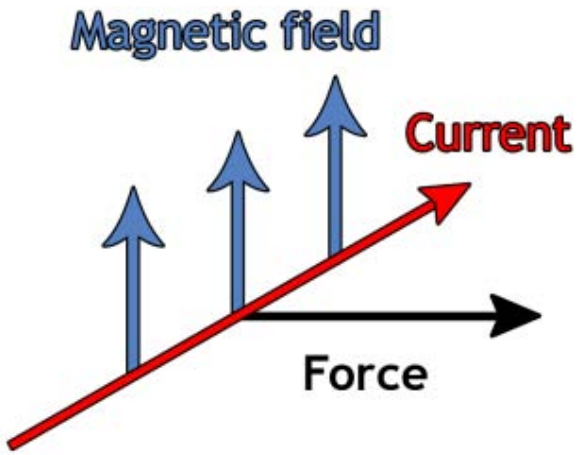
Gauss's Law:

$$E = -\hat{x}\,\frac{q}{\varepsilon_o A}$$

- **In electric field systems, force tends to increase capacitance**
- **In magnetic field systems, force tends to increase inductance**

Force on a current carrying wire

$$\overline{f} = q(\overline{E} + \overline{v} \times \mu_o \overline{H})$$



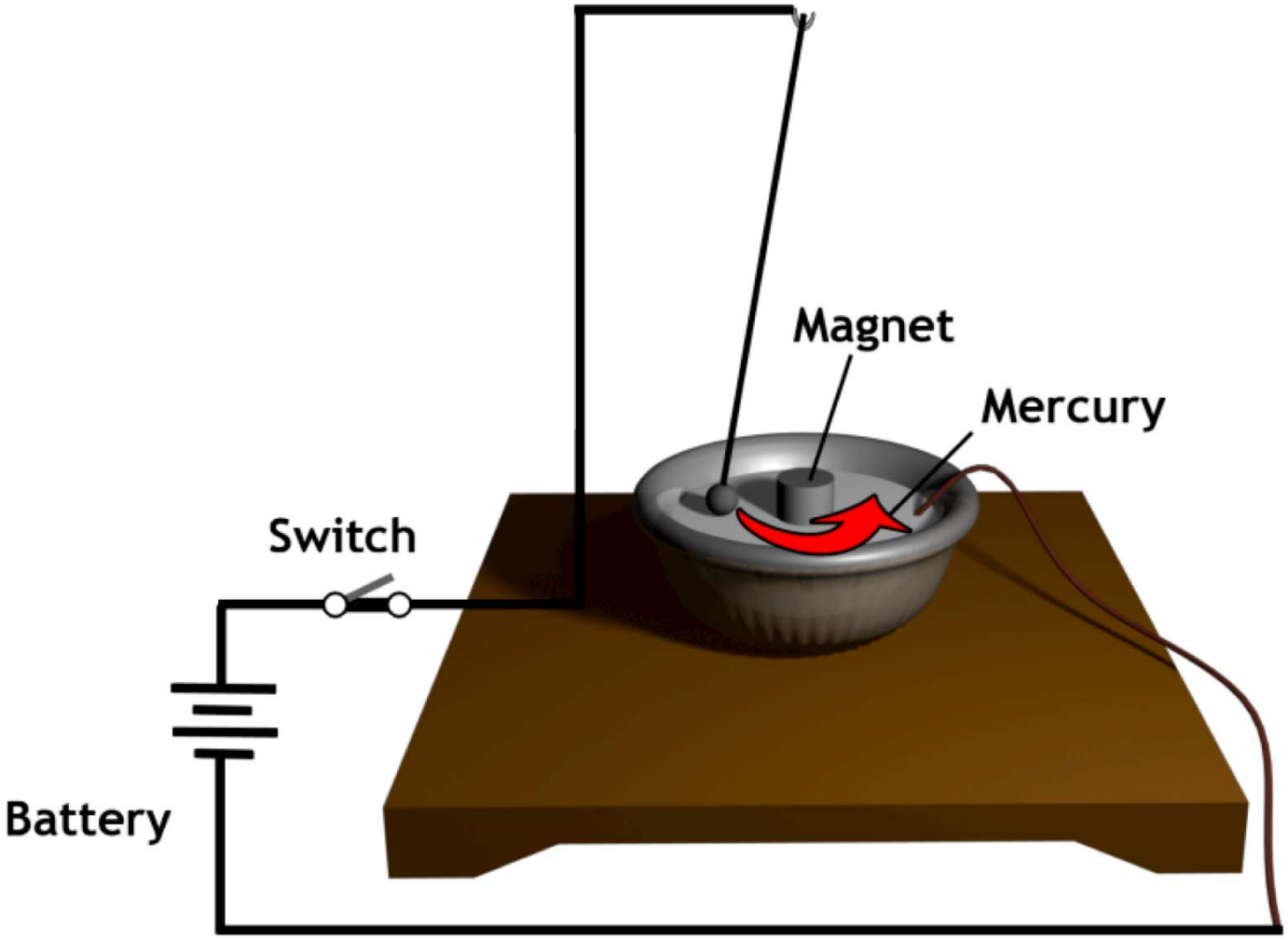
Note this follows the 'right-hand' rule

Section of wire in a magnetic field: force per unit length is:

$$\vec{f}_m = \vec{I} \times \mu_0 \vec{H}$$

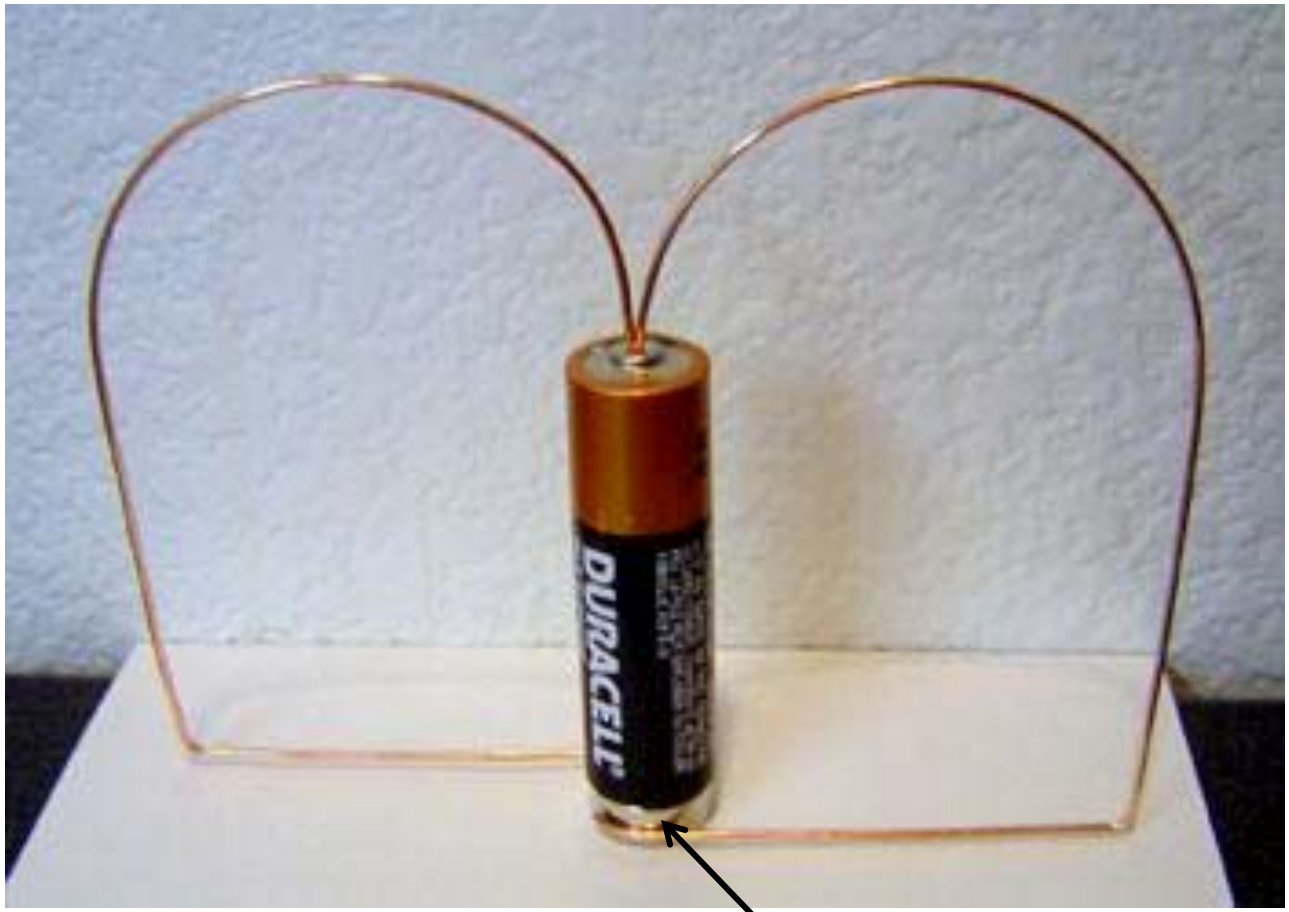
Check units: A X H/m X A/m = J/m^2 = N/m

First magnetic motor as created by Michael Faraday in 1821

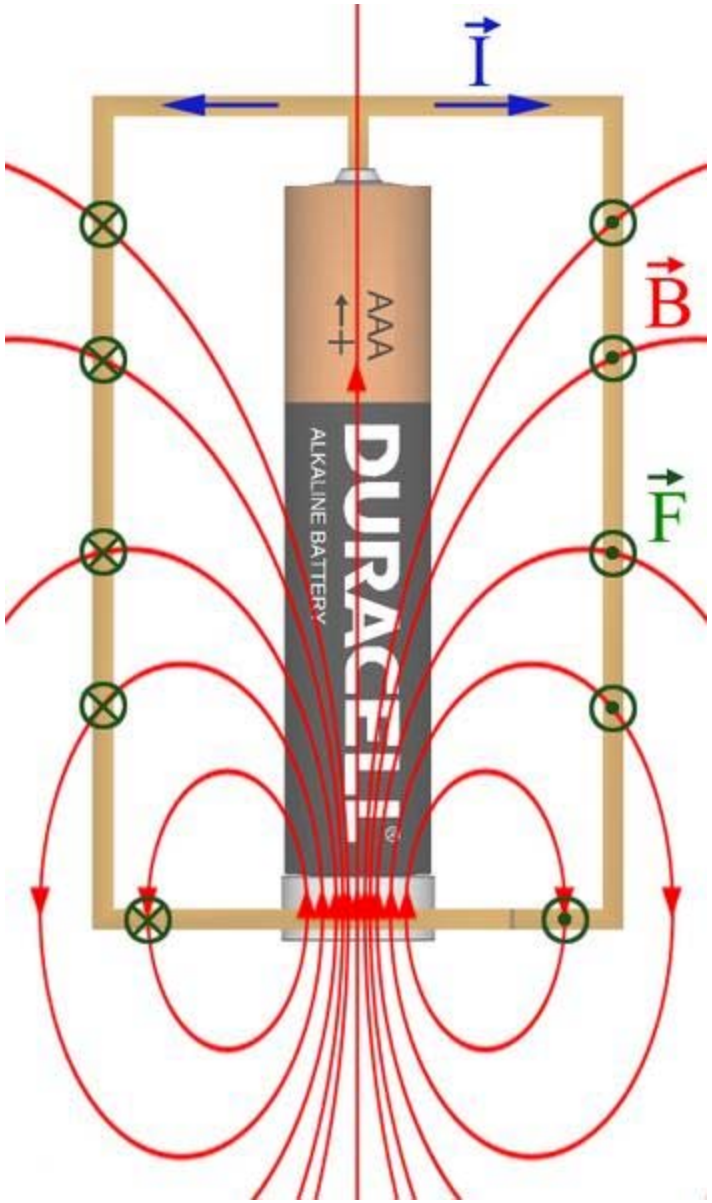


http://www.engineering-timelines.com/how/electricity/rotations.asp.

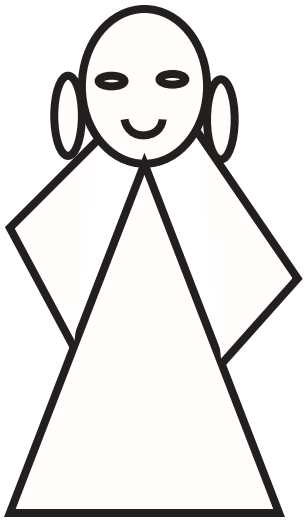
Homopolar Motor



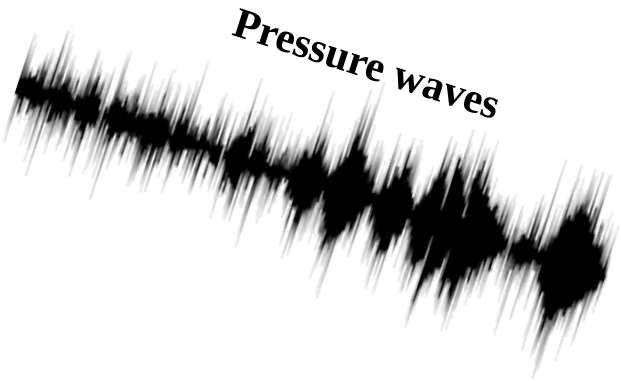
Homopolar Motor



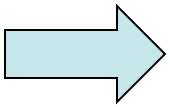
Speakers

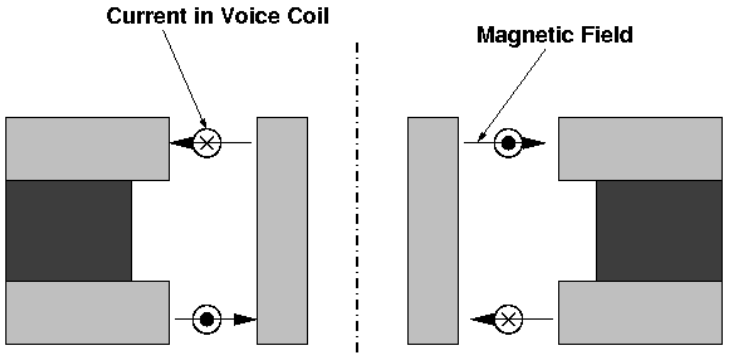


“Music! I feel happy, yay!”



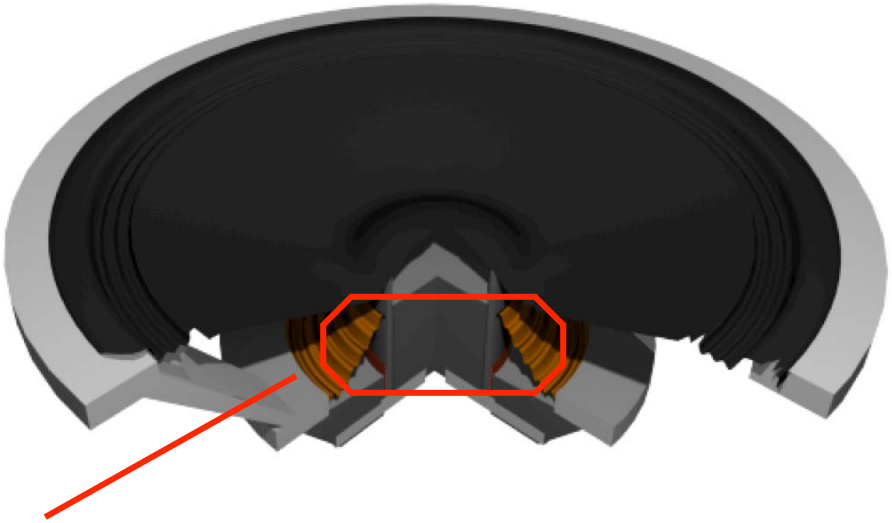
Current (I) waveform

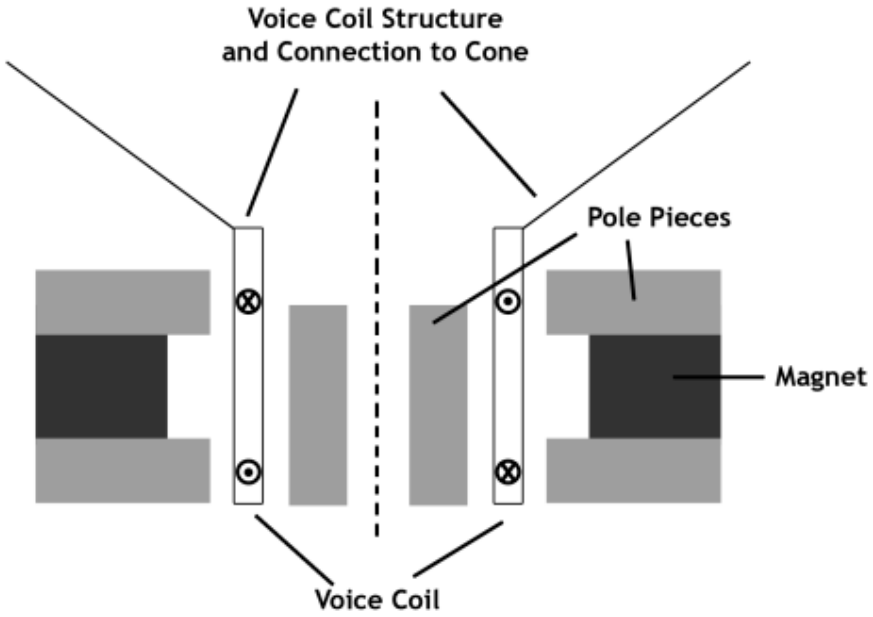




Loudspeaker

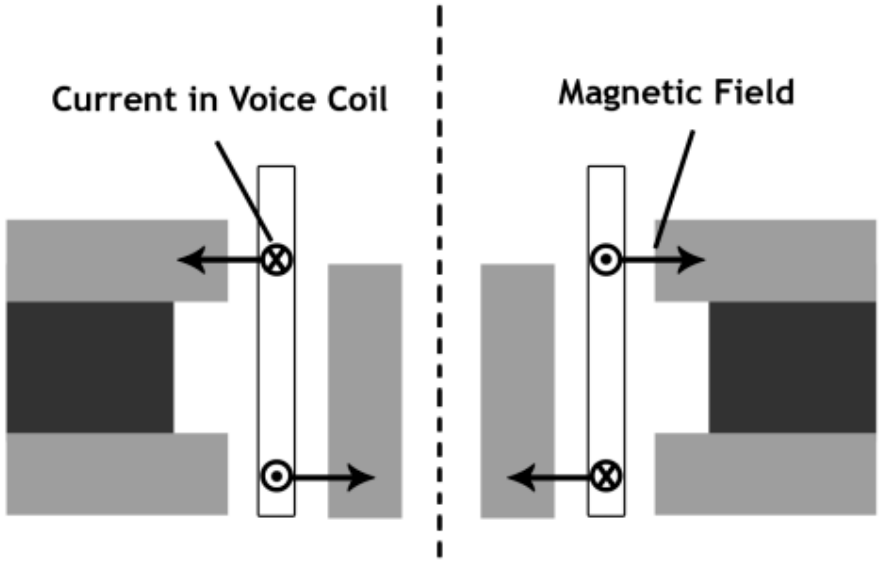
The loudspeaker is just a coil that makes a force applied to the paper cone. It has a low force spring to keep things centered (not shown below)





We will get to how the magnetic field is made later

http://static.howstuffworks.com/flash/speaker-working.swf



Force exerted on the voice coil: (up)

$$F = 2\pi RNI\mu_0 H_r = KI$$

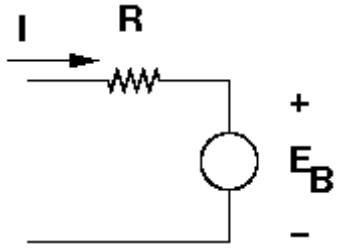
$$E_B = Ku$$

Suppose the voice coil is light and produces a force: $F = \beta u$

Then :

$$E_B = K\frac{F}{\beta} = \frac{K^2}{\beta} I = Z_0 I$$

And here is the electrical equivalent circuit



So now you know what they mean when they talk of an 8 ohm speaker.

Today's Culture Moment

Vocoders

A vocoder is an audio processor that captures the characteristic elements of an audio signal and then uses this characteristic signal to affect other audio signals. The technology behind the vocoder effect was initially used in attempts to synthesize speech. The effect called vocoding can be recognized on records as a "talking synthesizer", made popular by artists such as Stevie Wonder.

Image by snackfight on flickr http://www.flickr.com/photos/snackfight/3486304280/

Speakers

Photograph by davidking on Flickr.

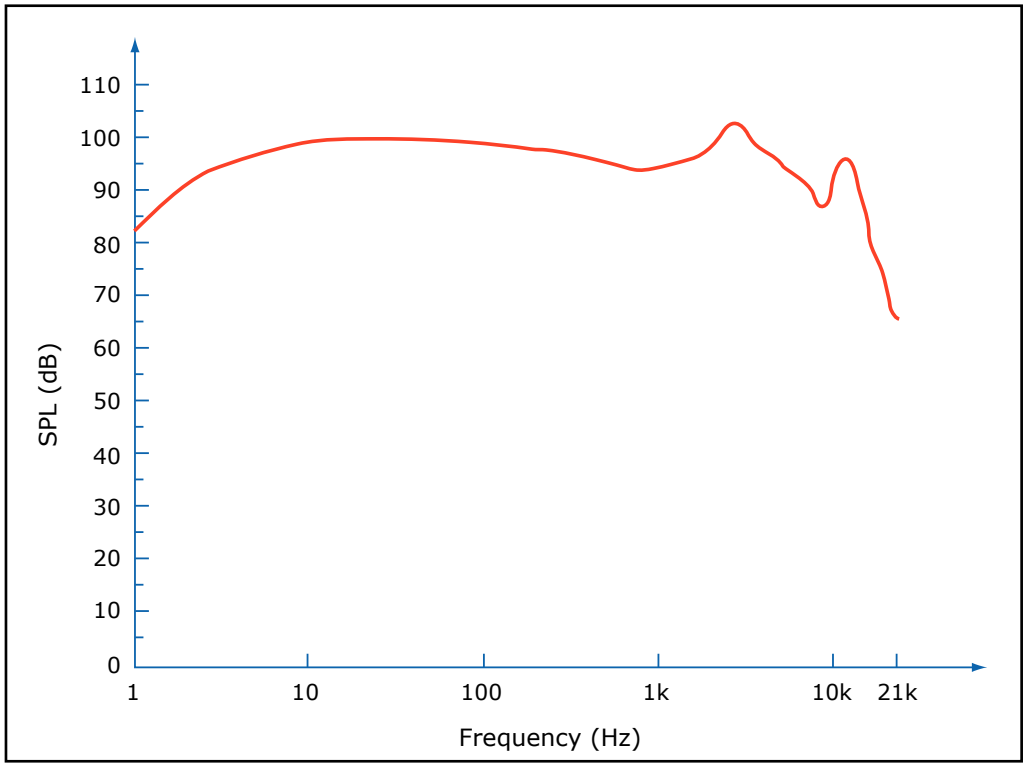
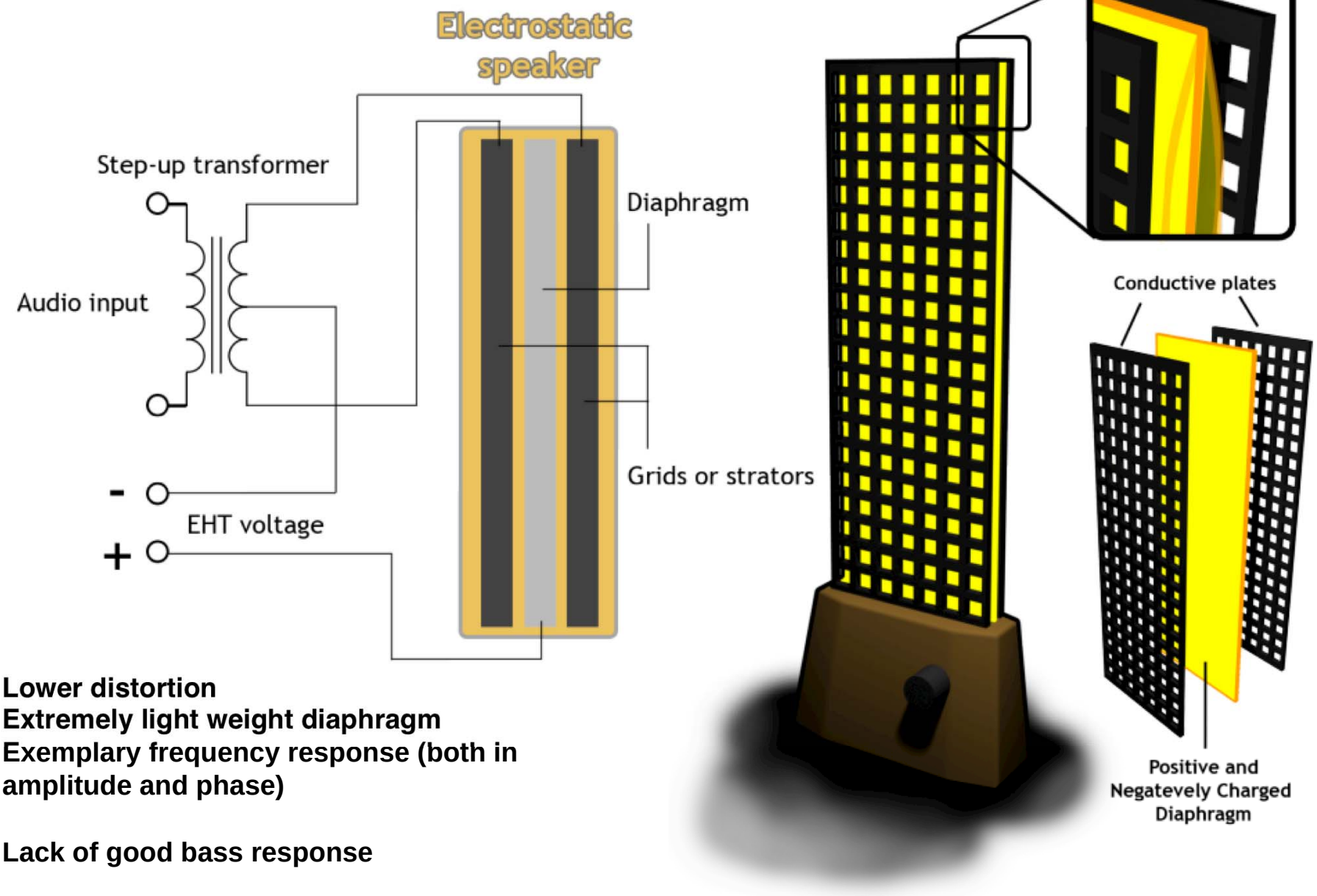


Image by MIT OpenCourseWare.

Why is it hard for earbuds to have good bass?

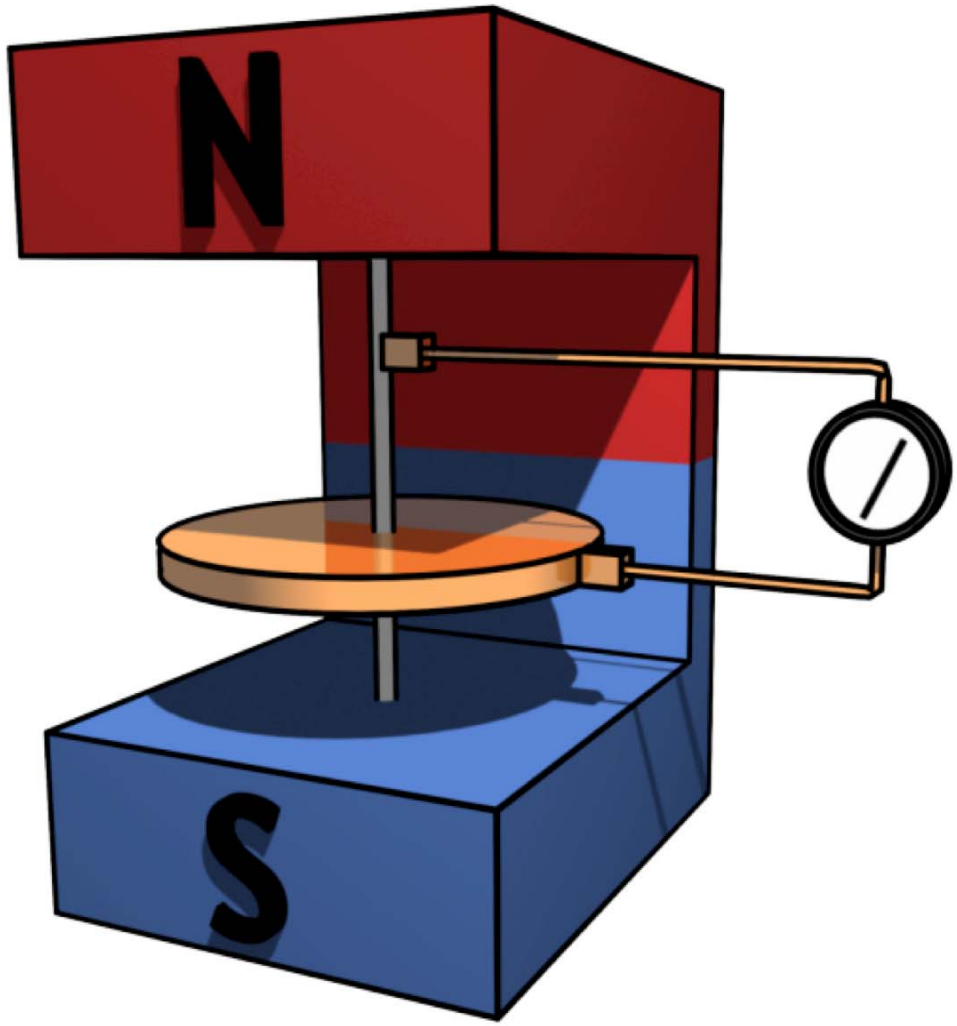
Electrostatic Speakers



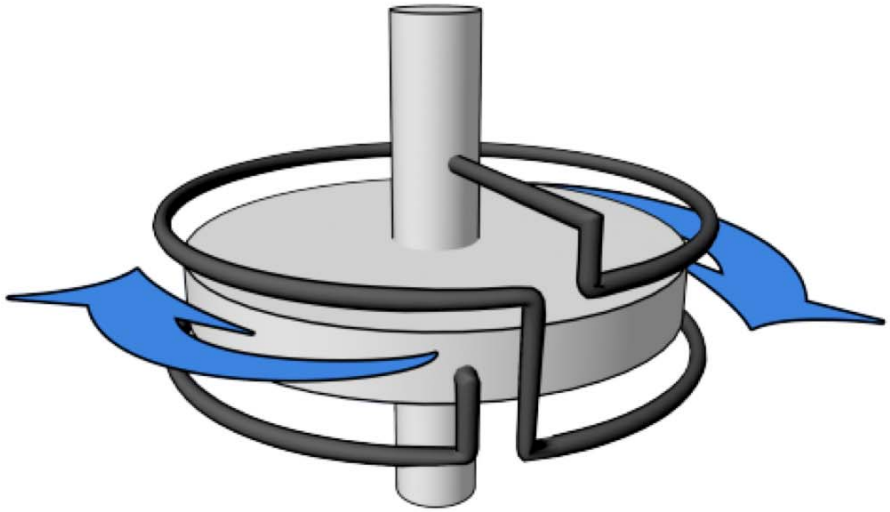
Lower distortion
Extremely light weight diaphragm
Exemplary frequency response (both in amplitude and phase)

Lack of good bass response

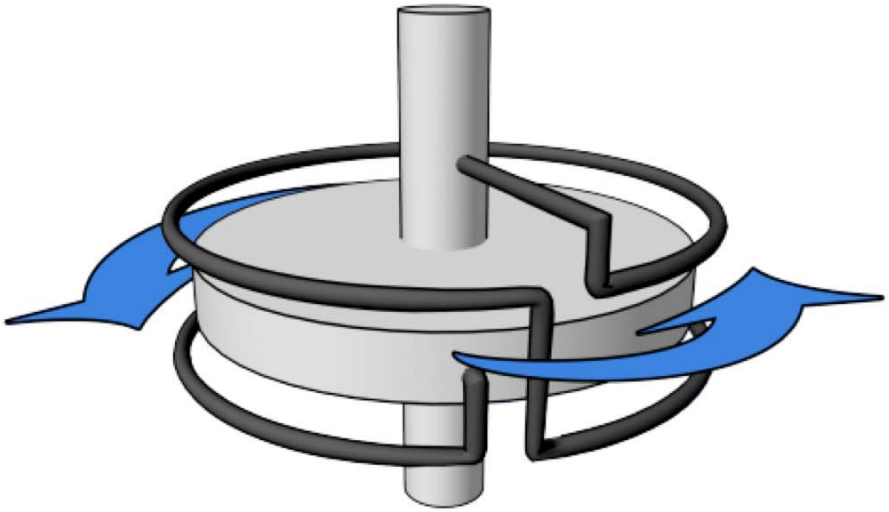
Homopolar Generator



Dynamo Brain Teaser



(a) Dynamo A



(b) Dynamo B

Only one of these devices can be a dynamo

Summary

- Lorentz force law $\overline{f} = q(\overline{E} + \overline{v} \times \mu_0 \overline{\mathrm{H}})$
- MEMs actuators (such as DLP arrays) rely on electrostatic attraction
- A commutator periodically reverses the current direction between the rotor
- Speakers (vibrating diaphragm) can utilize magnetostatic or electrostatic forces
- Induced current is always in such a direction as to oppose the motion or change causing it

6.007 Electromagnetic Energy: From Motors to Lasers
Spring 2011