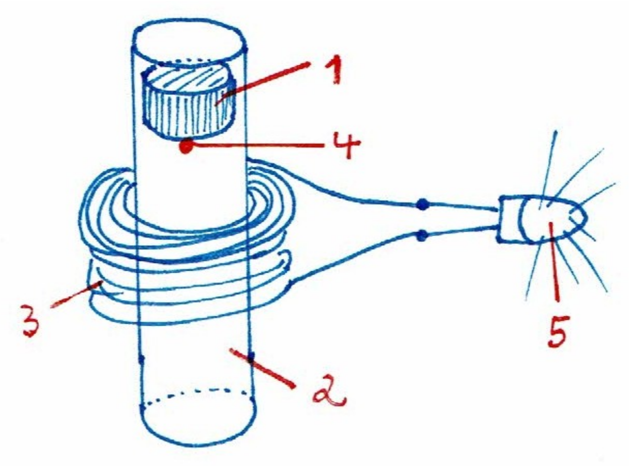
Induction flashes

Calculation of the number of turns N of an induction coil



1 neodymium round magnet
2 plastic tubes (e.g. tablet tubes)
3 induction coil (self-wound)
4 Location where the magnetic field strength is to be calculated
5 LED

Experiment:
A neodymium magnet in a plastic tube is moved by shaking it through an induction coil. An LED is connected to this.
Observation:
The diode flashes briefly each time the magnet passes through the coil.

Task:
Roughly estimate the number of turns N of the coil!
Known:
The neodymium magnet has a strength ("remanence") of 1.2 T.
The diode ignites

$$U_{Dio} = 1{,}8\ V$$

(Note: Your operating current should be as small as possible, e.g. 2 mA)

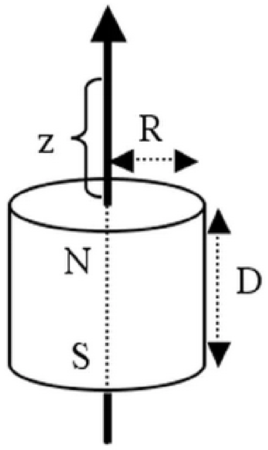
Solution:
First of all, we estimate the magnetic flux density B ("magnetic field strength") directly in front of the magnet. This gives us the magnetic flux change that occurs in the induction coil when the magnet is immersed in it. We take a reasonable estimate of the duration of the immersion and then use the induction law to calculate the induction voltage in one turn of the coil. The desired number of turns is then obtained from the desired ignition voltage of the diode.

Flux density B:
We use a formula for a cylindrical permanent magnet:

Formel für Flussdichte Zylindermagnet

Formel für das B-Feld auf der Symmetrieachse eines axial magnetisierten Zylindermagneten (Scheibe oder Stab):

$$B = \frac{B_r}{2}\left(\frac{D+z}{\sqrt{R^2+(D+z)^2}} - \frac{z}{\sqrt{R^2+z^2}}\right)$$



B_r: Remanenzfeld, unabhängig von der Geometrie des Magneten (siehe Physikalische Magnet-Daten)

z: Abstand auf der Symmetrieachse von einer Polfläche

D: Dicke (bzw. Höhe) des Zylinders

R: Halber Durchmesser (Radius) des Zylinders

Die Längeneinheit ist beliebig wählbar, solange sie für alle Längen gleich ist.

https://www.supermagnete.de/faq/Wie-berechnet-man-die-magnetische-Flussdichte

Br is the "remanence" field strength, e.g. 1.22 Tesla for a "Grade" N38 neodymium magnet.

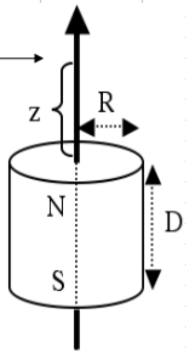
For a round magnet with a radius of 5 mm and a height of 5 mm, the formula gives an axial value of 0.43 Tesla directly on the top surface:

Zylinder (Scheibe/Stab)

2R	D	R	D	2D	Grade	Br	Beschichtung	Distanz z	z Tot.	Br/2	sum1	sum2
10	5	0,01	0,01	0,01	N38	1,22	0	0	0	0,61	0,71	0
mm	mm	m	m	m		T	m	mm	m			

Flussdichte im Abstand z von einem Zylinder

B(z)	0,430	4298
	Tesla	Gauss



$$B = \frac{B_r}{2}\left(\frac{D+z}{\sqrt{R^2+(D+z)^2}} - \frac{z}{\sqrt{R^2+z^2}}\right)$$

Since the field strength certainly decreases with the distance from the axis, it is sensible to work with a significantly smaller (average) value, for example
B = 0.3T

The magnetic flux is calculated

$$\Phi = B \cdot A$$

with the top surface

$$A = r^2\pi = (5mm)^2\pi = 25\pi\, 10^{-6} m^2 \approx 78 \cdot 10^{-6} m^2$$

This results in

$$\Phi = 23 \cdot 10^{-6}\, Tm^2$$

The law of induction is

$$U_i = \frac{\Delta\Phi}{\Delta t}$$

the time Δt in which the magnetic field in the coil increases from (practically) zero to the maximum value. With fast shaking e.g. a value of Δt = 1/100 s makes sense.

This results in the induction voltage for one turn:

$$U_i = 2{,}3\ mV$$

and the number of turns is calculated

$$N = \frac{U_{Dio}}{U_i} = \frac{1{,}8\ V}{2{,}3\ mV} = 7{,}8 \cdot 10^2$$

Since the estimation was only rough in several points, it can only be said that several hundred windings are necessary!

Category	
Title	Induction flashes, Law of Induction
Physical subject matter	Electromagnetism, Induction
Learning level (1-5)	5
Preparation difficulty (1-3)	3
Price per set (€)	2
Attractiveness (1-3)	3
Standart-exotic (1-3)	3
Instructions set-up	yes
Instructions execution	yes