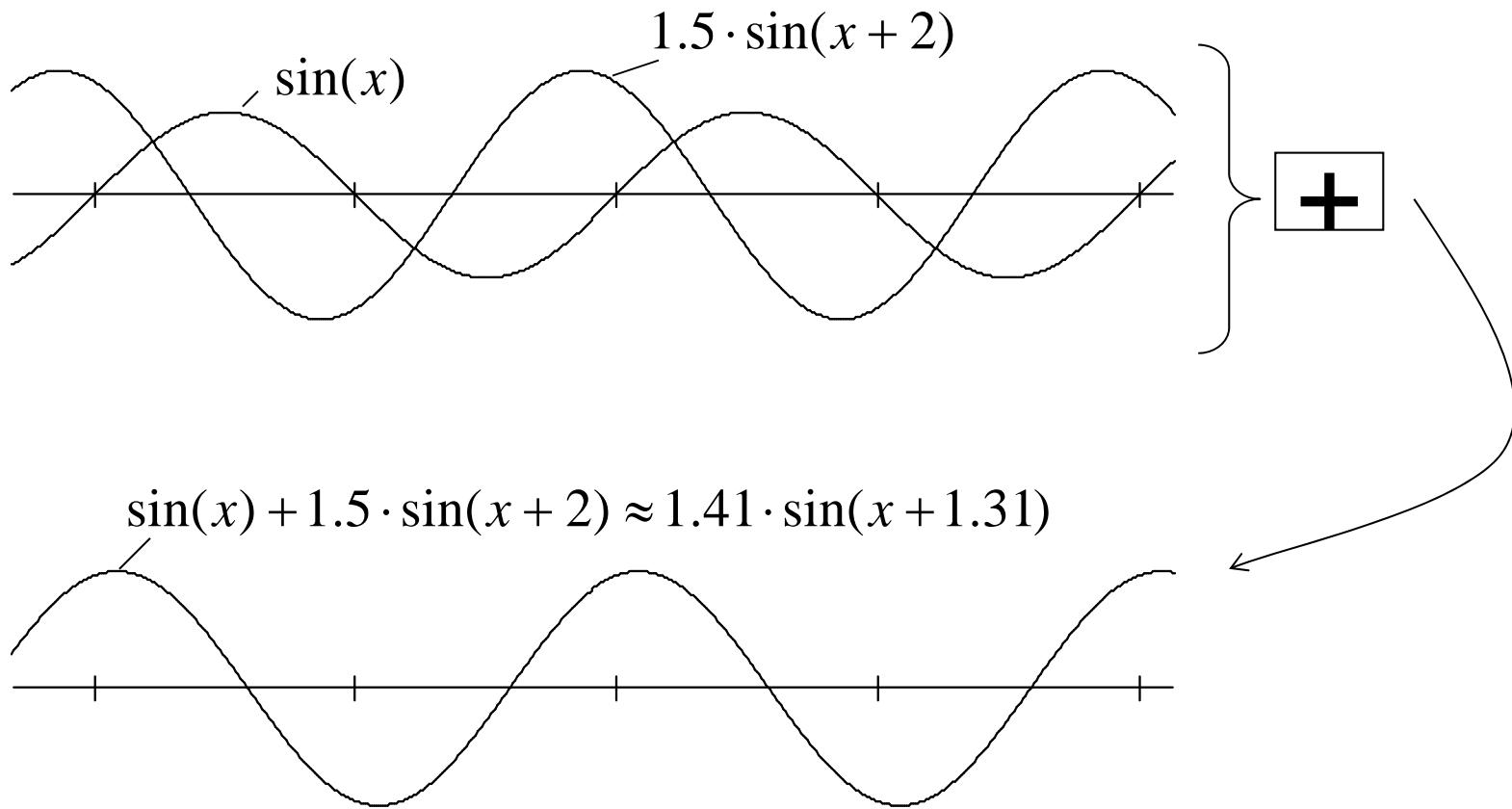


# **Ton und Farbe bei Young, Goethe und Helmholtz**

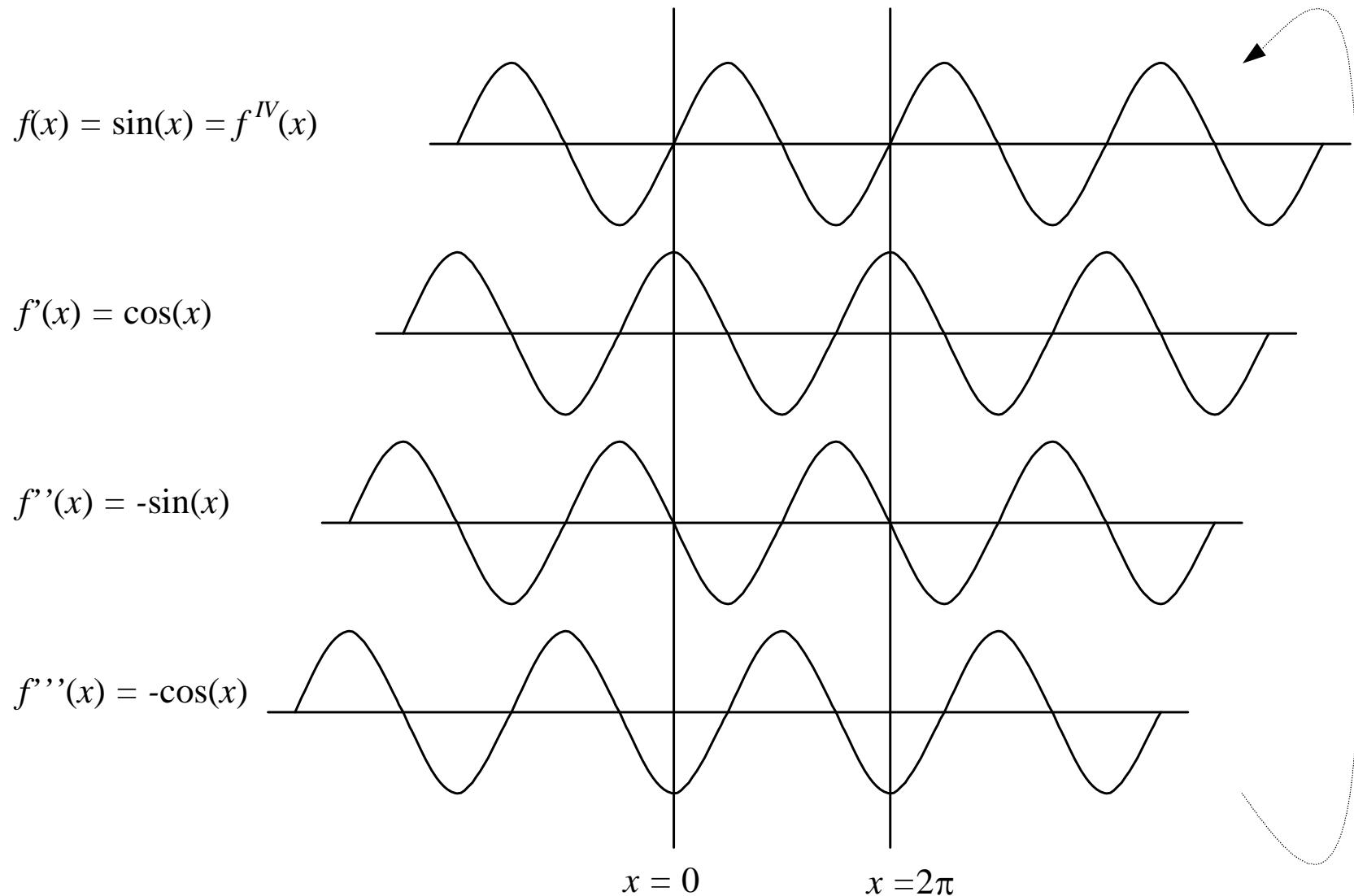
Daniel Muzzolini

2011

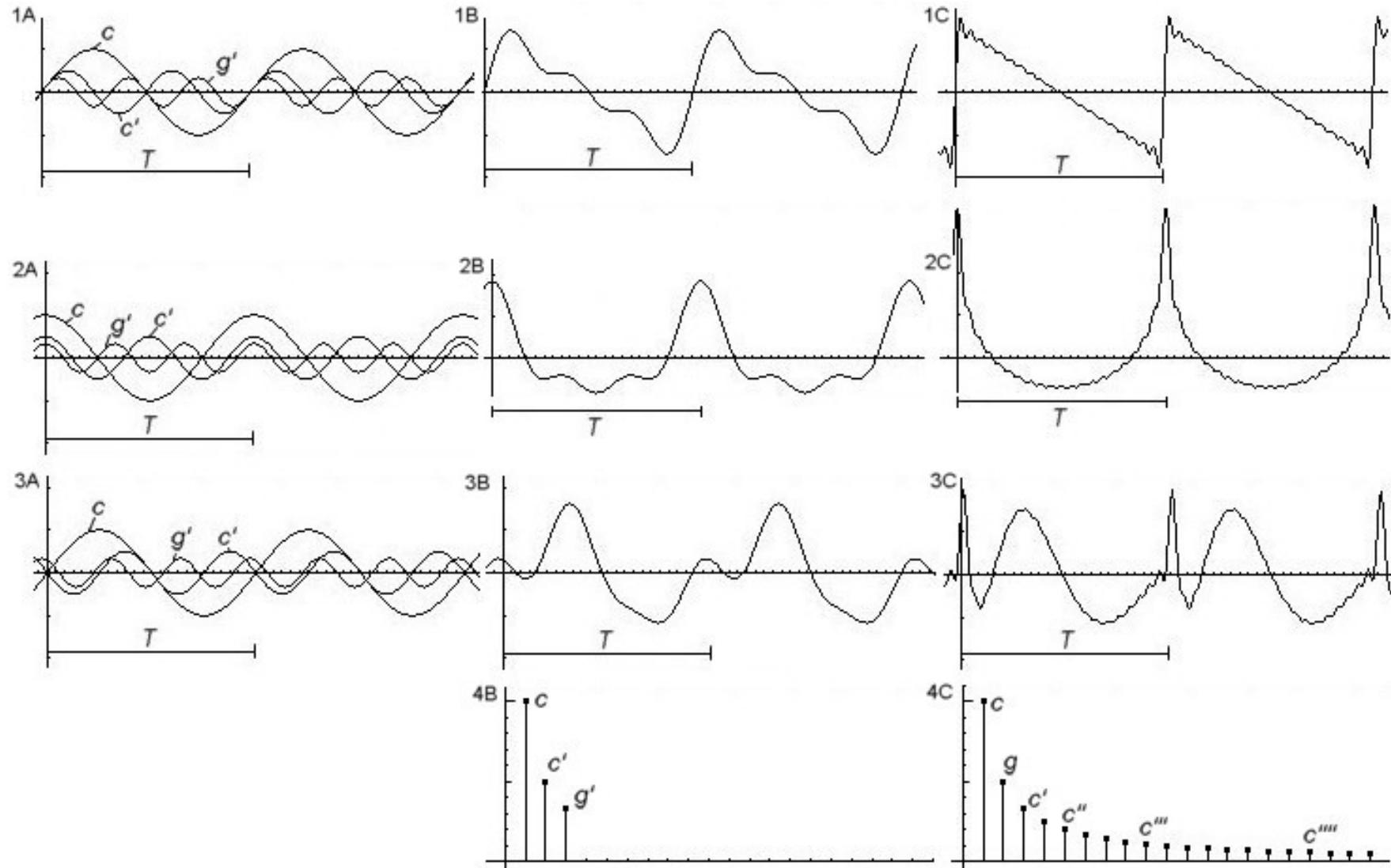
# Warum Sinusschwingungen?



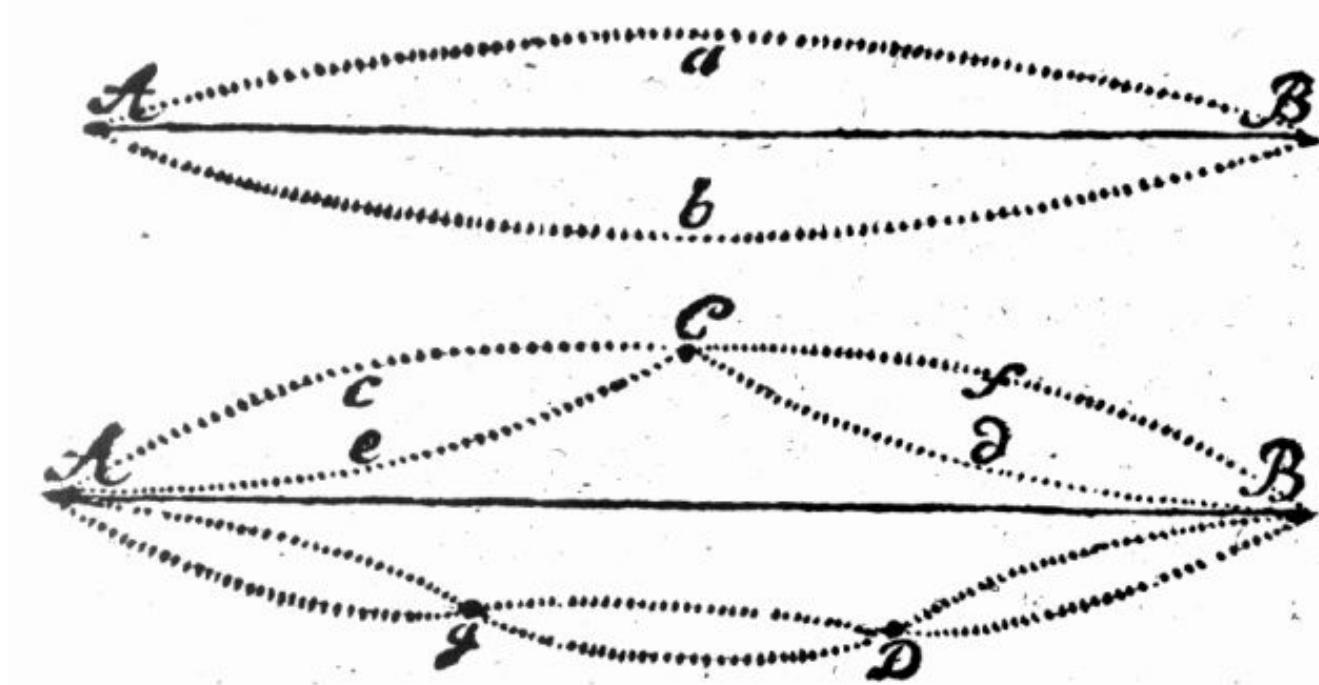
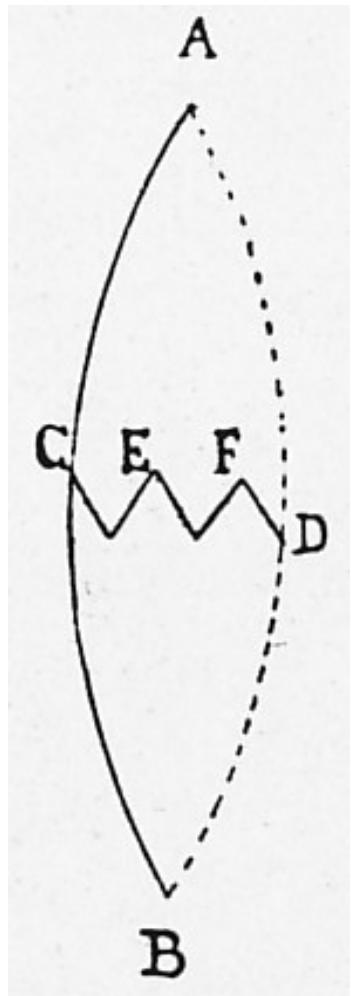
# Warum Sinusschwingungen? (2)



# Ohm'sches Gesetz der Akustik

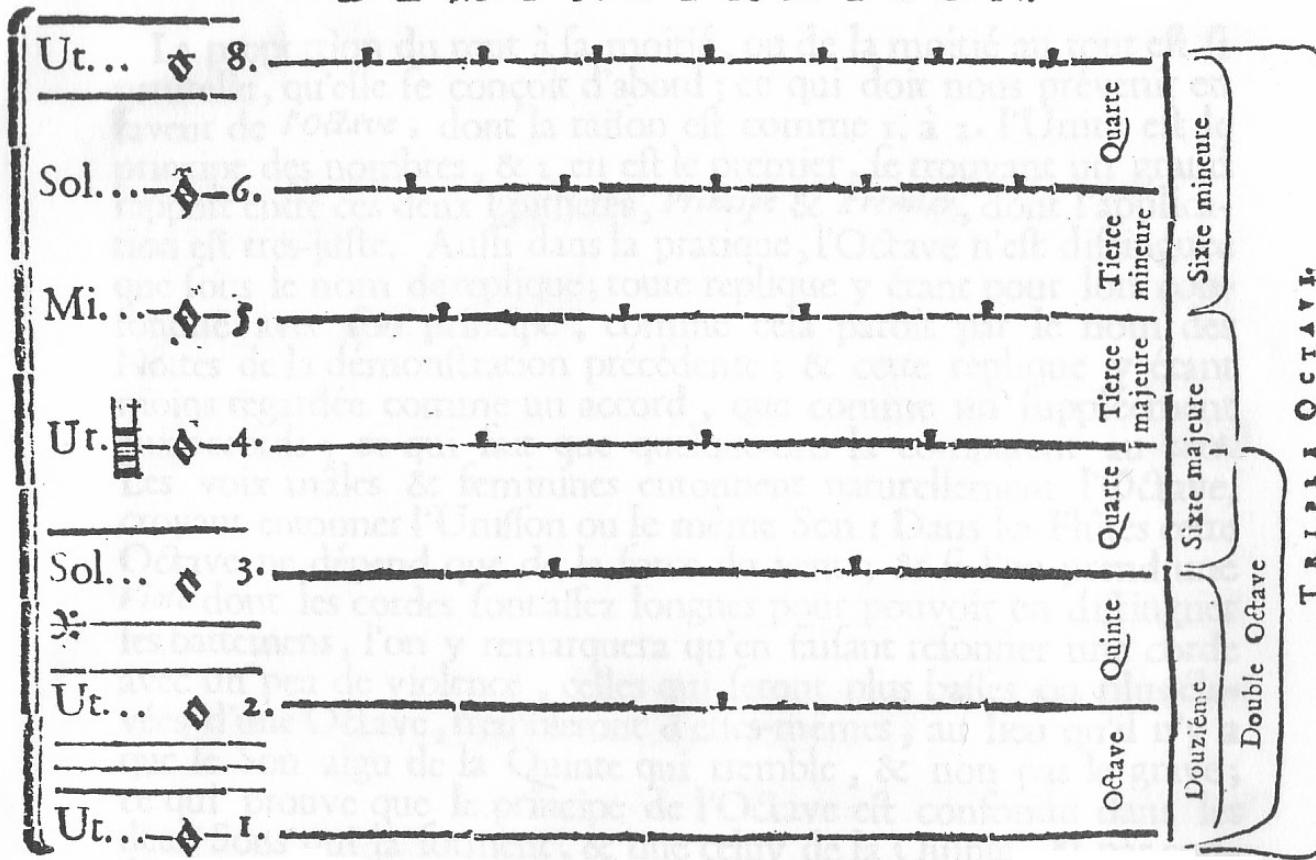


# René Descartes 1633 / Johann Georg Sulzer 1774: Obertöne



# Jean-Philippe Rameau 1722/37: Trinité und Cacophonie

## DÉMONSTRATION.



{ mi. si. solx. sol. ré. si. si. fax. réx. }

s. 15. 25. 6. 18. 30. 15. 45. 75. }

# Christiaan Huygens 1673 (?)

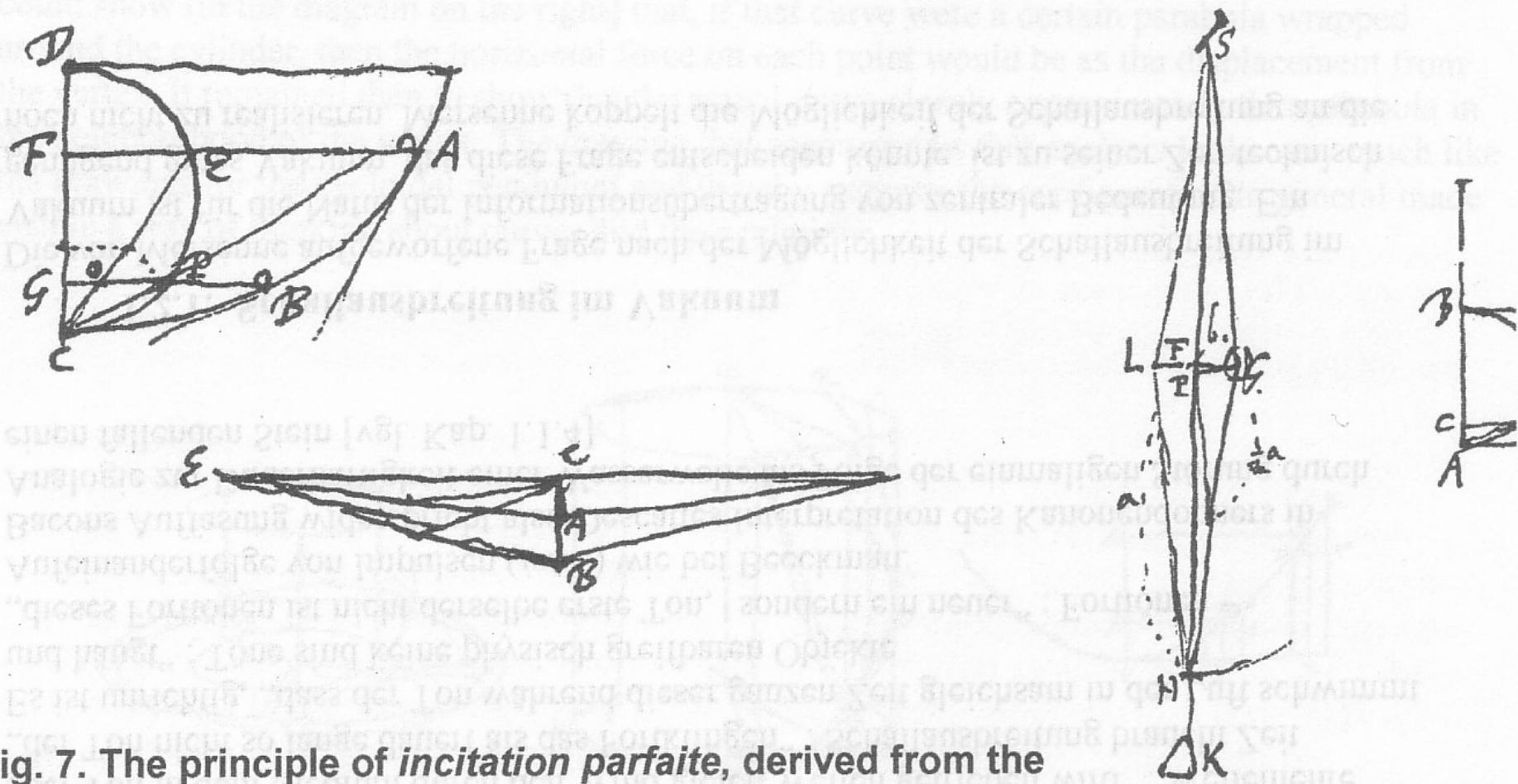
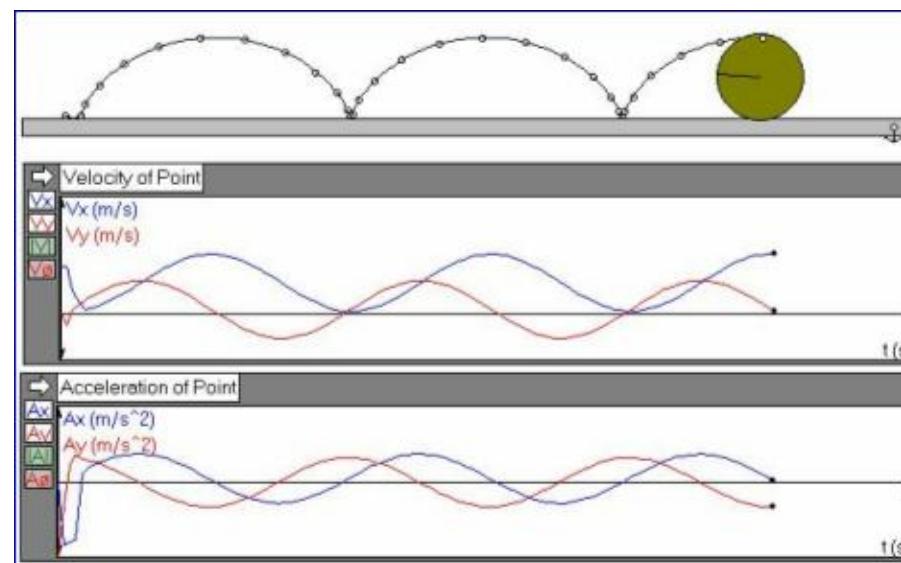
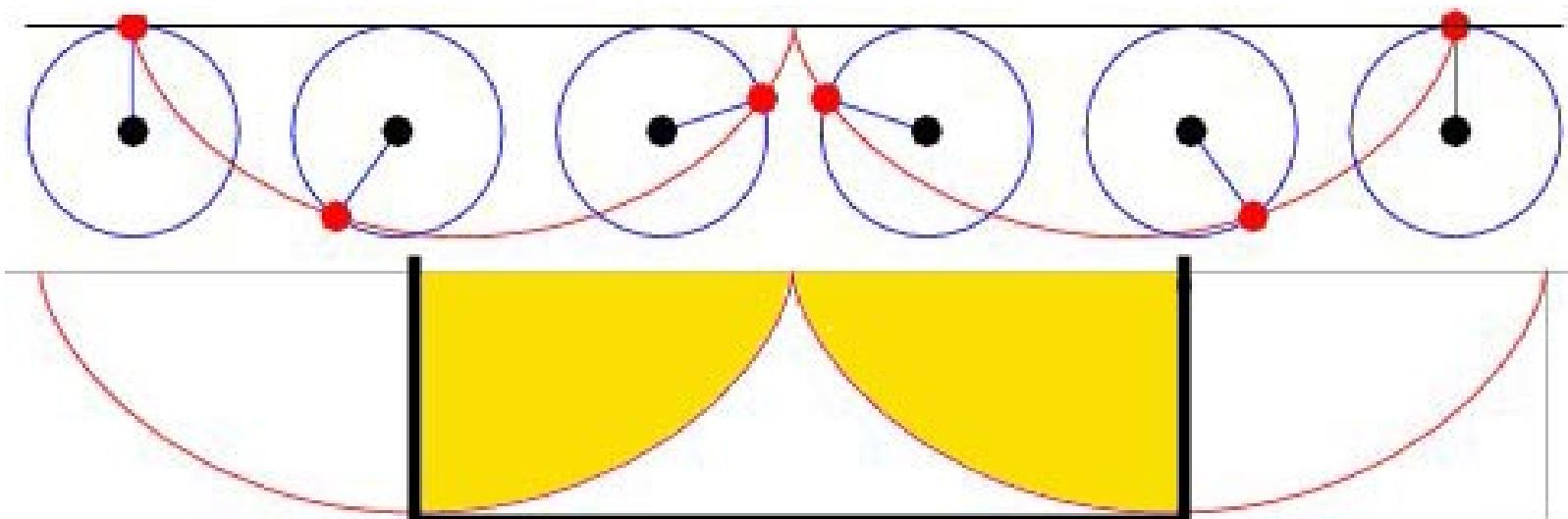
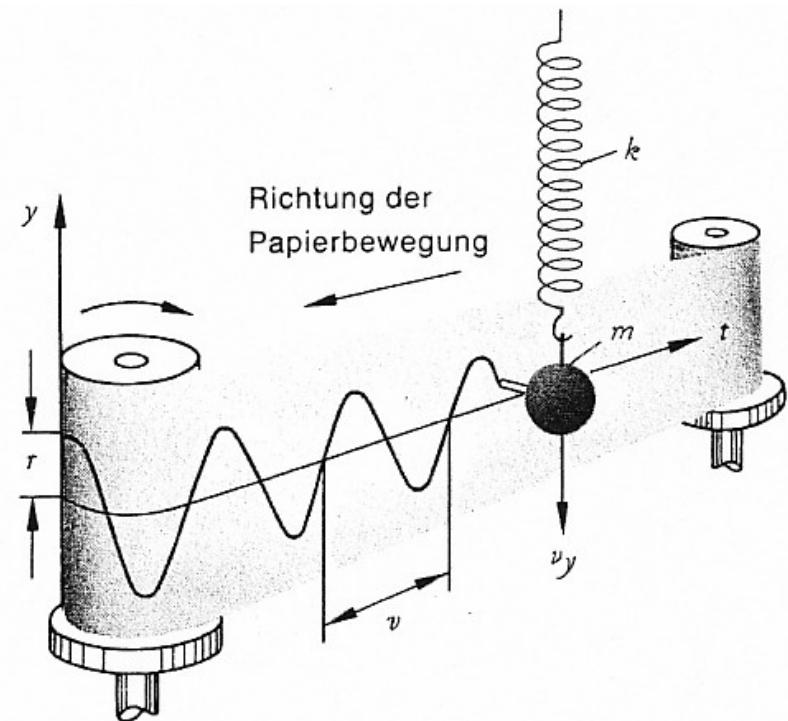
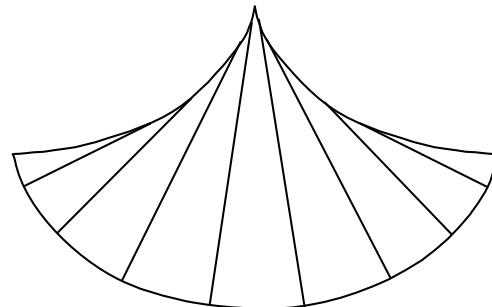
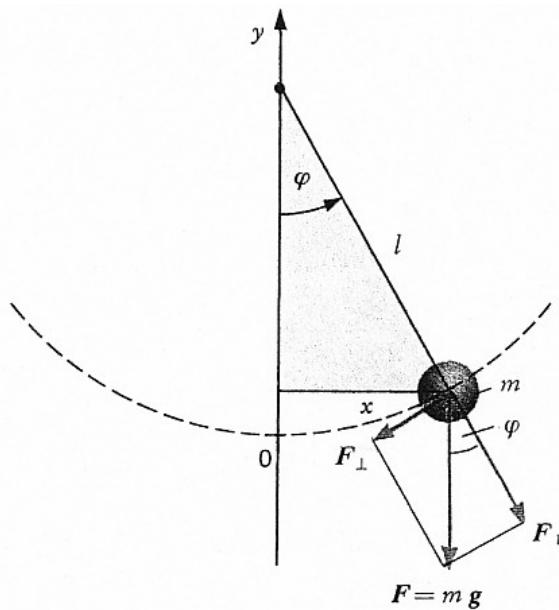


Fig. 7. The principle of *incitation parfaite*, derived from the cycloid and applied to a vibrating string; HOC, 18:489-490.

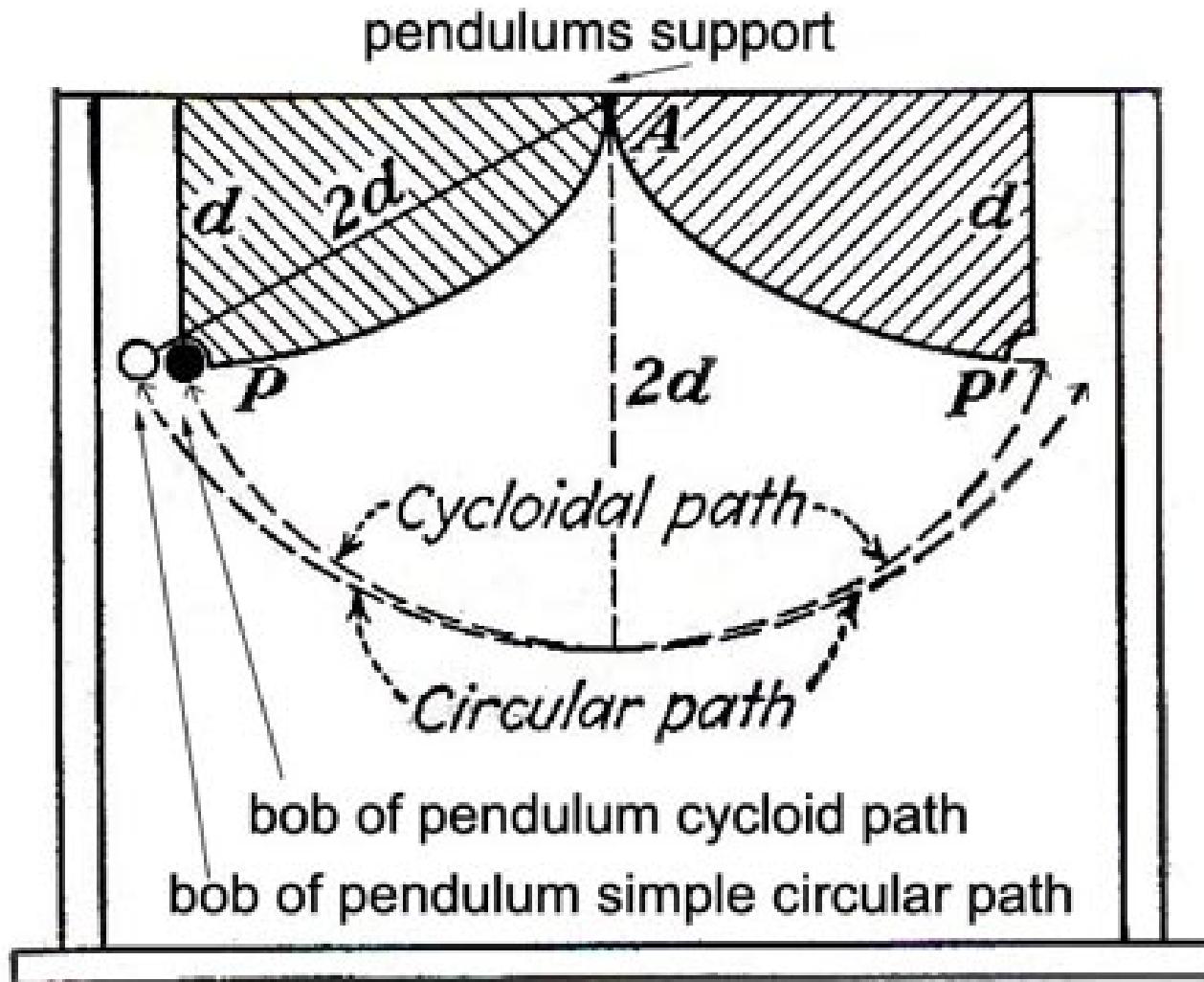
# Zykloide



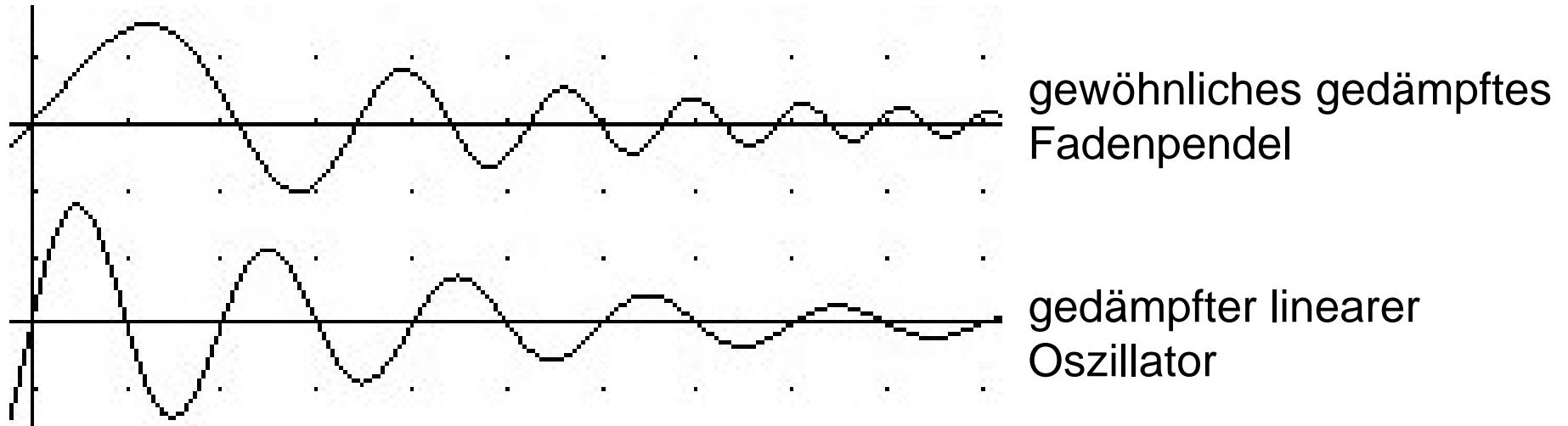
# Faden-, Zykloiden- und Federpendel



# Zykloidenpendel versus Fadenpendel



# Zykloidenpendel und gedämpftes Fadenpendel



# Roberts Smith 1749

PL.XXIII.Pag: 276.

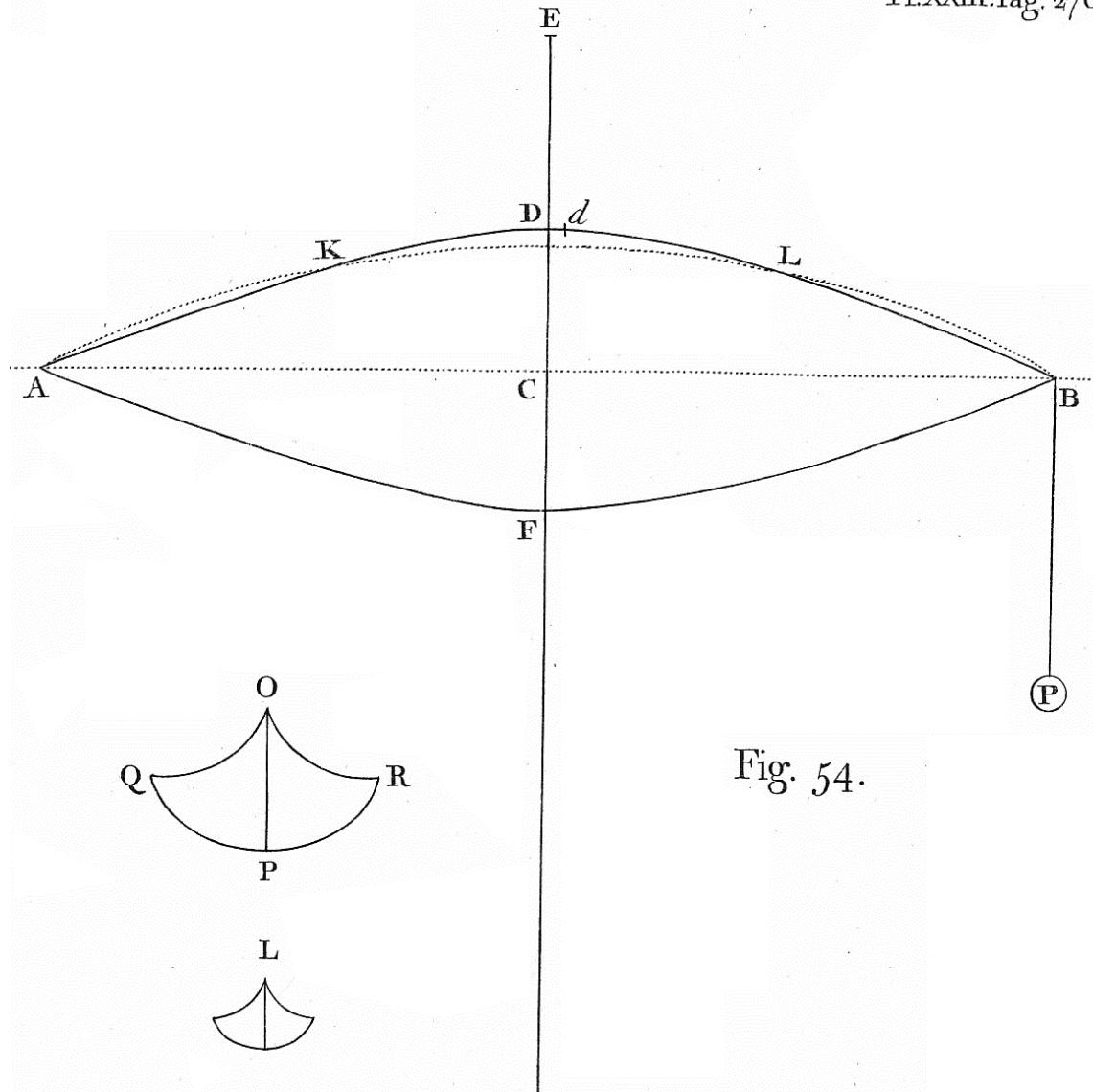


Fig. 54.

# Leonhard Euler 1748/65: periodische Störungen

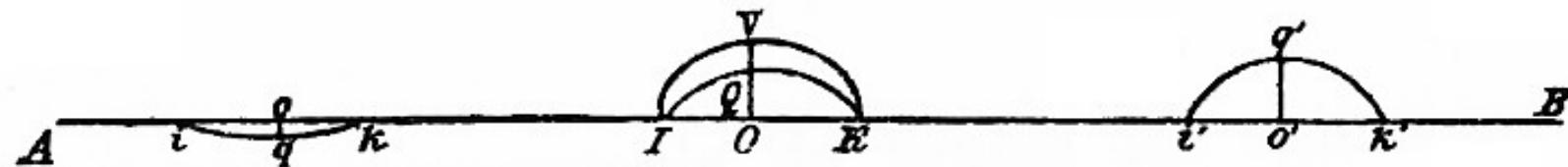
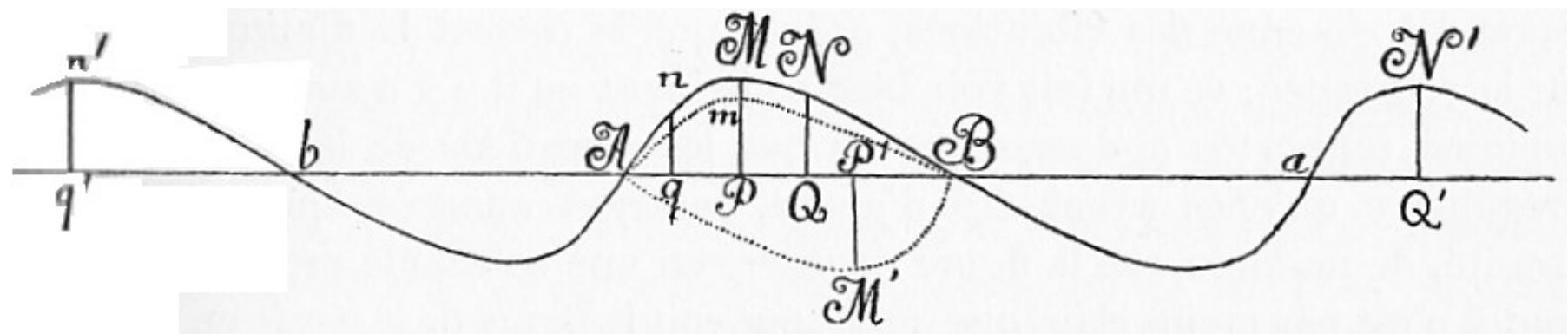


Fig. 4.

# Thomas Young 1800: gezupfte Saite

Fig. 47

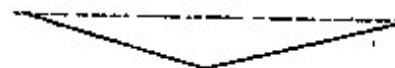
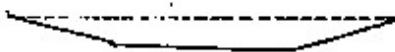
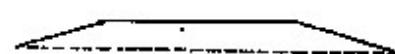
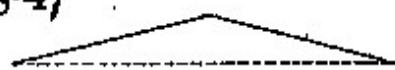
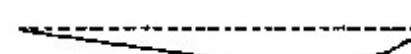
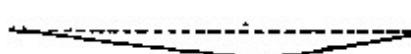
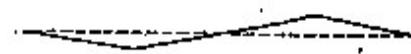
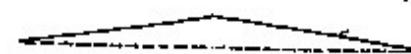
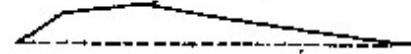
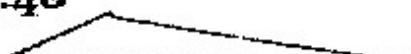


Fig. 48



# Thomas Young: Schwebungen

Fig. 41

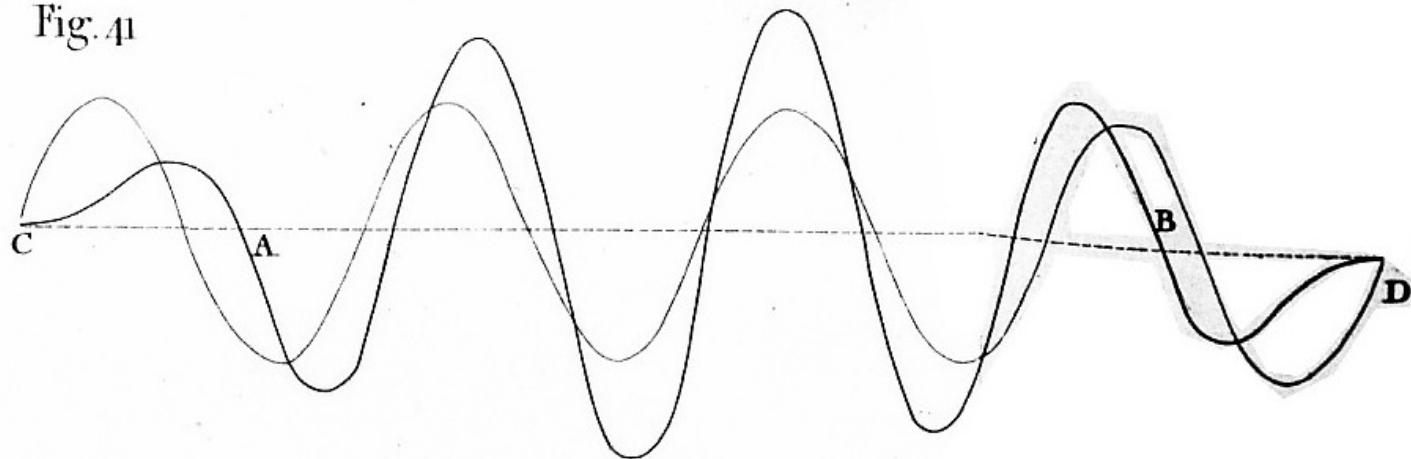


Fig 43

A

B

C

D

E

# Thomas Young

Fig. 36

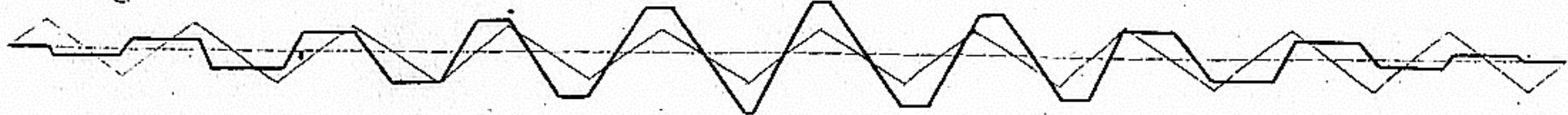


Fig. 37

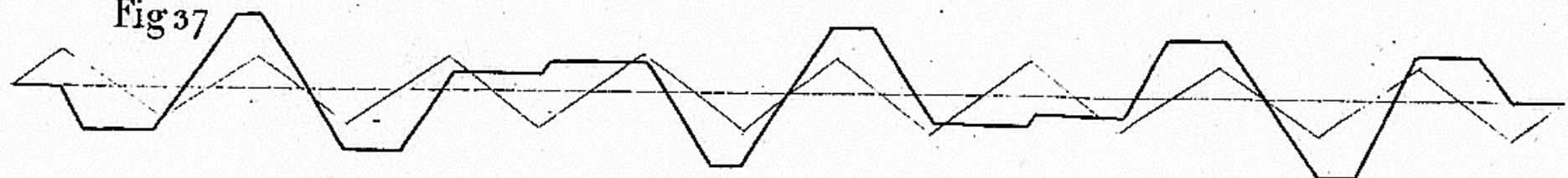
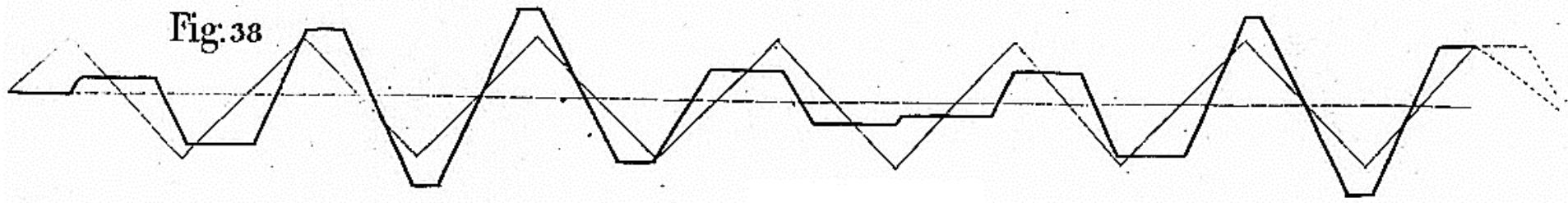


Fig. 38



# Thomas Young

Fig. 39

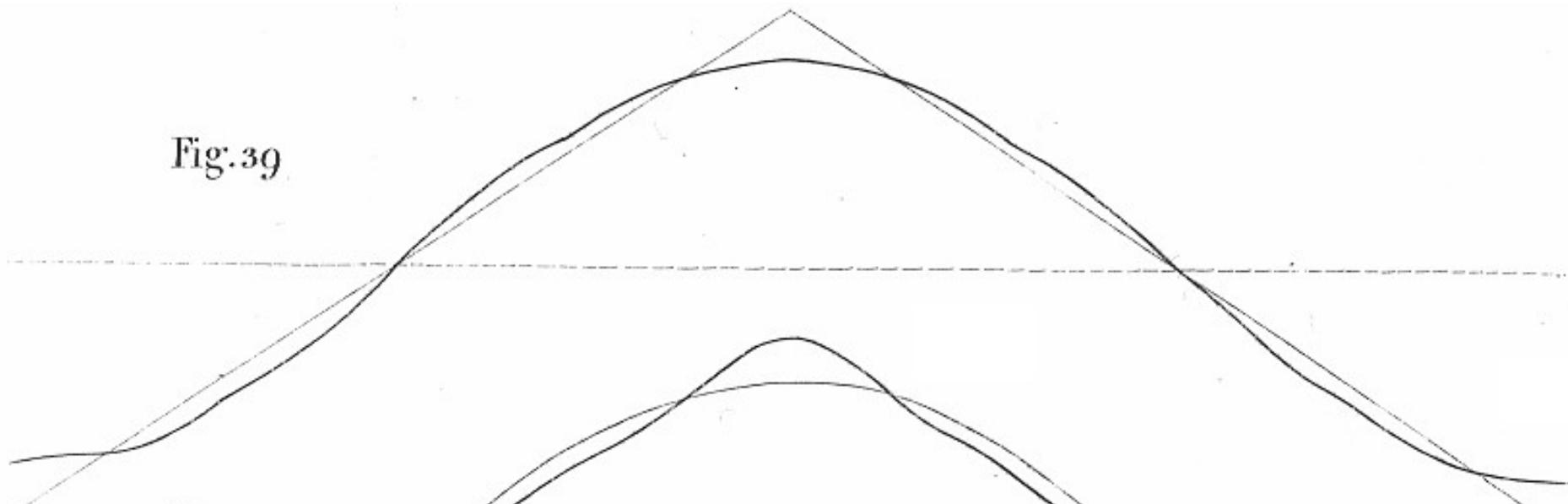
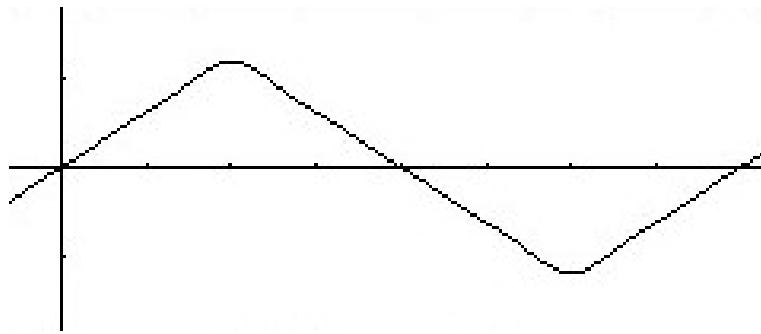


Fig. 40

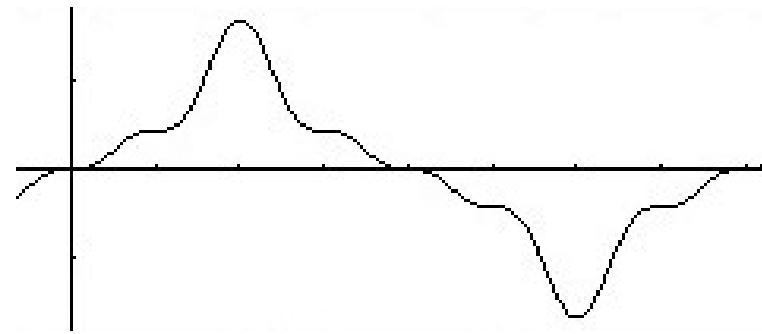


# Sinussynthese der Dreiecksschwingung

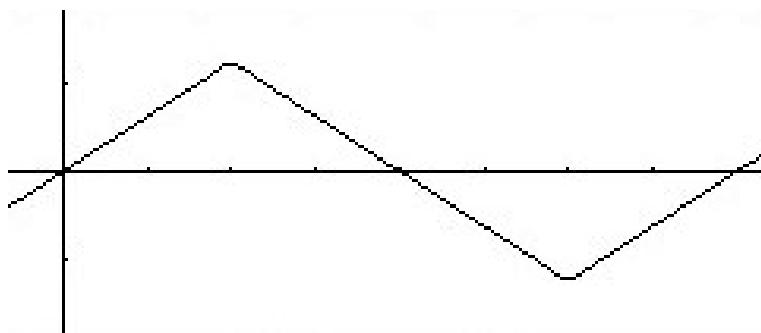
(a)



(c)



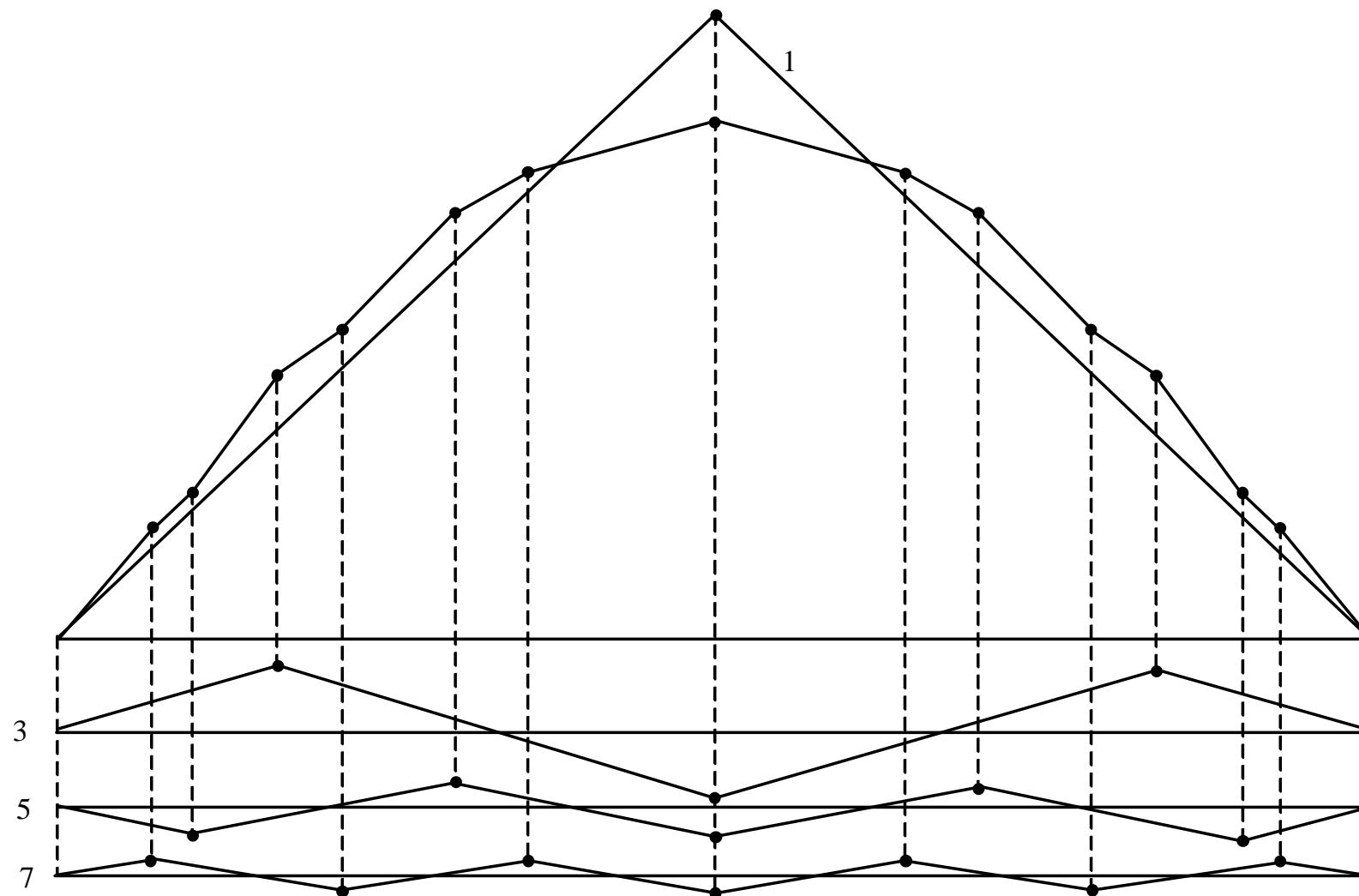
(b)



(d)



# Dreieckssynthese der Sinusschwingung



# Dreieckssynthese Rechnung

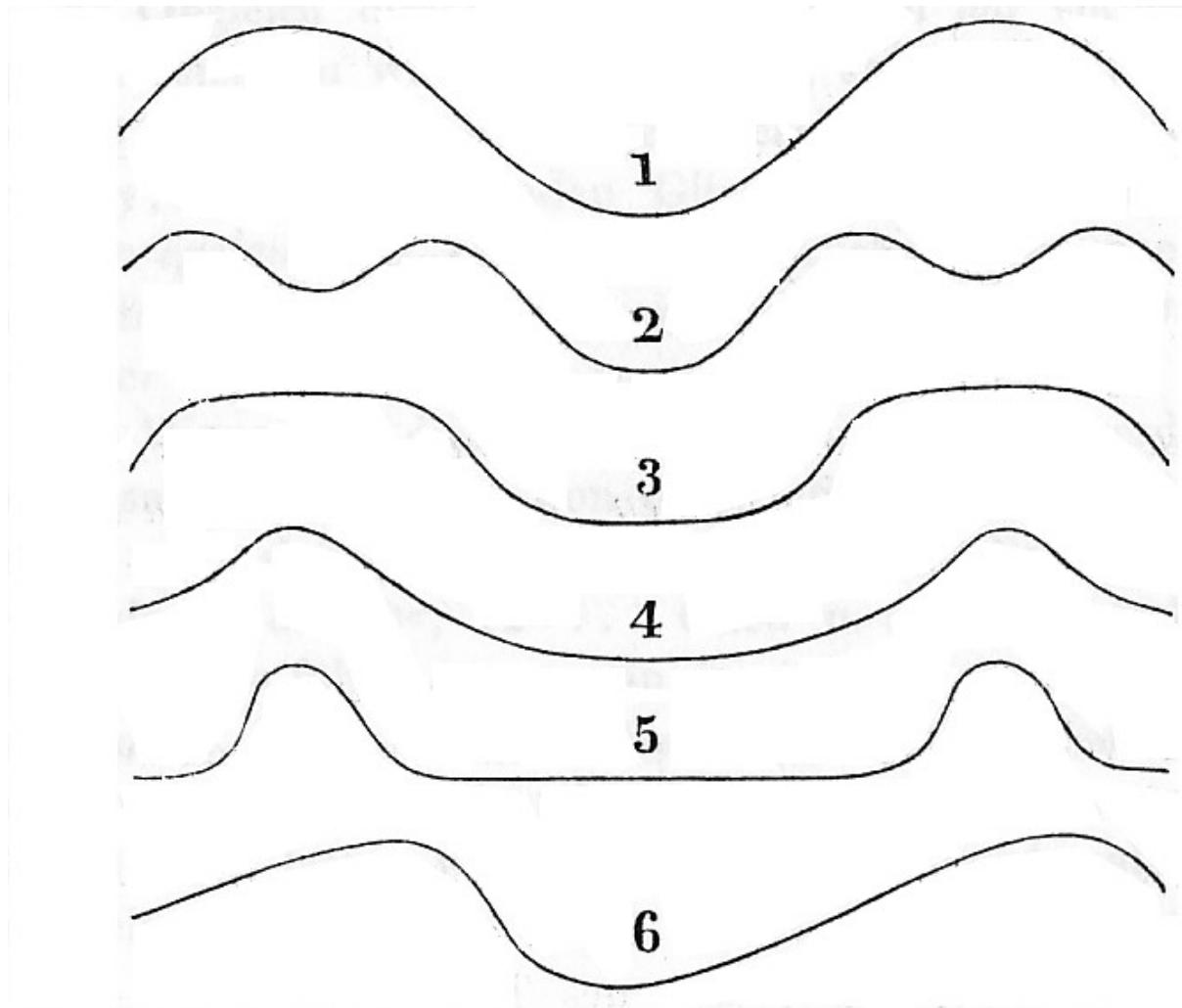
Beispiel N=15

1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
-1/9	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1/25	0	0	0	1	0	0	0	0	0	0	0	0	0	0
0	-1/9	0	0	0	1	0	0	0	0	0	0	0	0	0
-1/49	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1/81	0	-1/9	0	0	0	0	0	1	0	0	0	0	0	0
0	1/25	0	0	0	0	0	0	0	1	0	0	0	0	0
-1/121	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	-1/9	0	0	0	0	0	0	0	0	1	0	0	0
1/169	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	-1/49	0	0	0	0	0	0	0	0	0	0	0	1	0
-1/225	0	1/25	0	-1/9	0	0	0	0	0	0	0	0	0	1

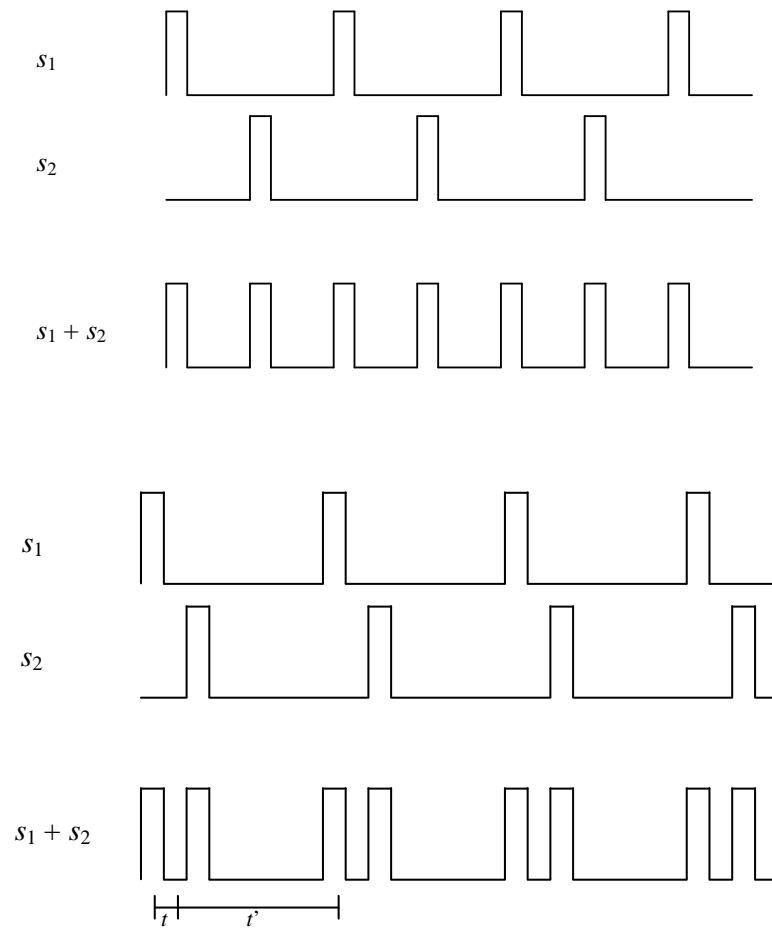
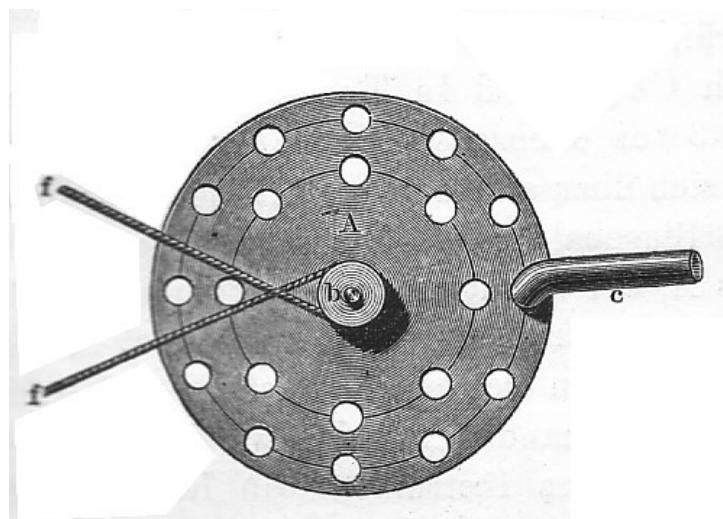
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
1/9	0	1	0	1	0	1	0	1	0	1	0	1	0	1
0	0	0	1	0	0	1	0	0	1	0	0	1	0	0
-1/25	0	0	0	1	0	0	1	0	0	1	0	0	1	0
0	1/9	0	0	0	1	0	0	0	1	0	0	0	1	0
1/49	0	0	0	0	1	0	0	0	0	1	0	0	0	1
0	0	0	0	0	0	1	0	0	0	0	1	0	0	1
0	1/9	0	0	0	0	0	1	0	0	0	0	1	0	0
-1/25	0	0	0	0	0	0	0	1	0	0	0	0	1	0
1/121	0	0	0	0	0	0	0	0	1	0	0	0	1	0
0	0	1/9	0	0	0	0	0	0	0	0	0	0	1	0
0	-1/25	0	1/9	0	0	0	0	0	0	0	0	0	0	1
-1/169	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	1/49	0	0	0	0	0	0	0	0	0	0	0	0	1
-1/225	0	-1/25	0	1/9	0	0	0	0	0	0	0	0	0	0

11

# Ohm / Seebeck: Definition des Tons

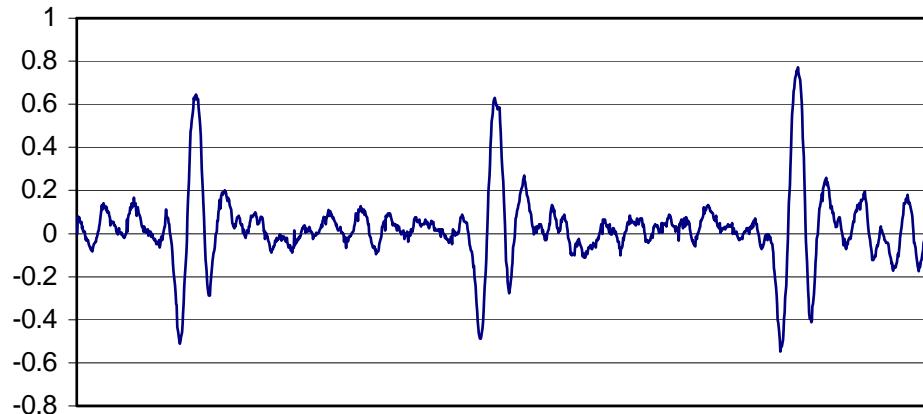


# Lochsirene

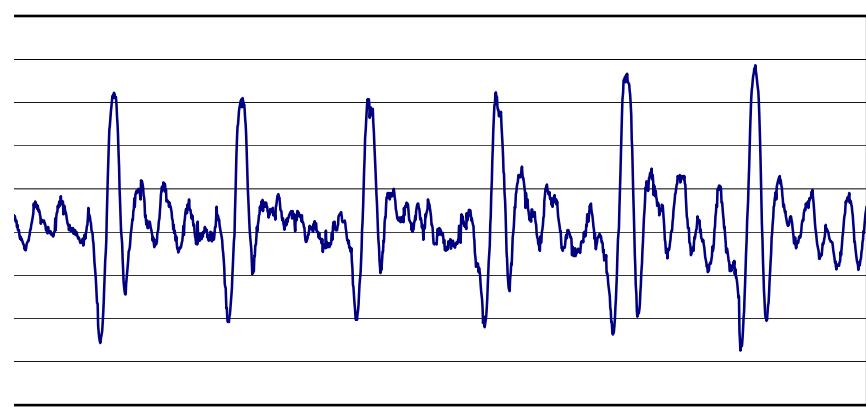


# Lochsirene (versch. LK)

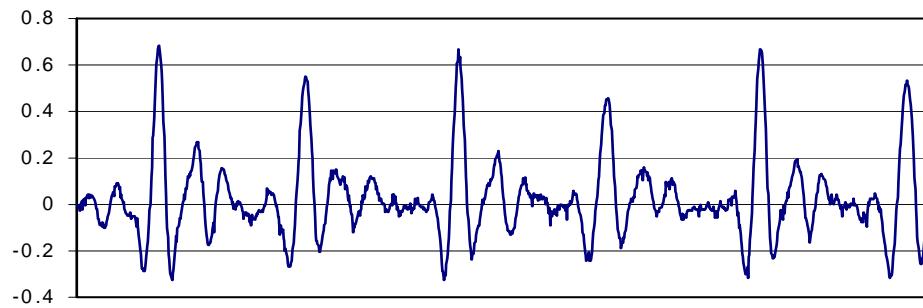
Ik03plus04\_01



Ik03plus04\_01 + transl

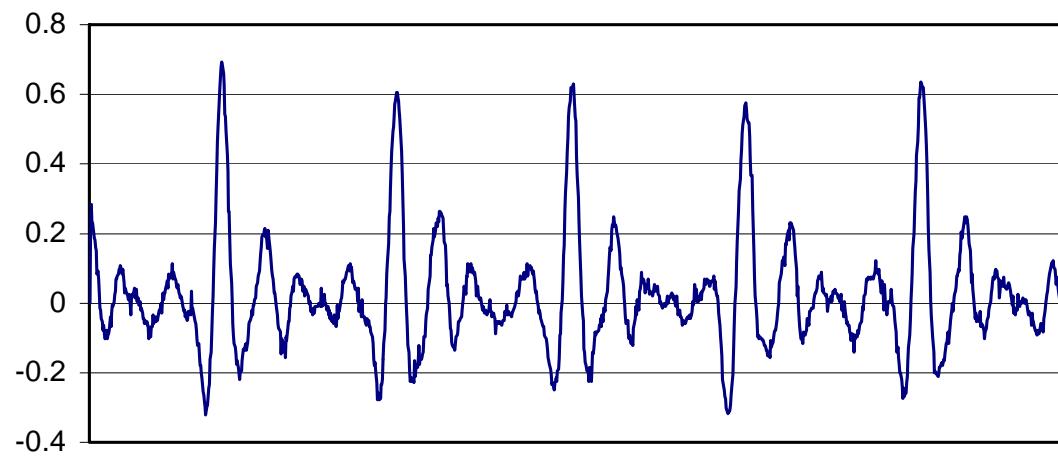


Ik03plus04\_02

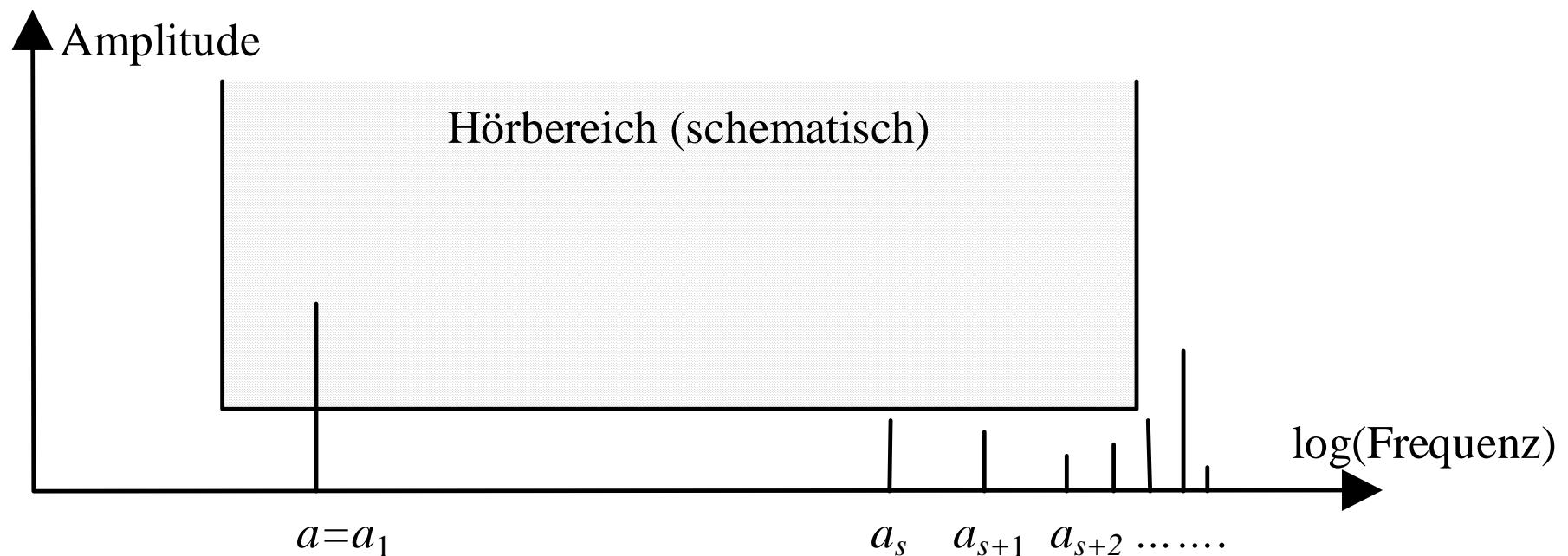


# Lochsirene (gleicher LK versetzt)

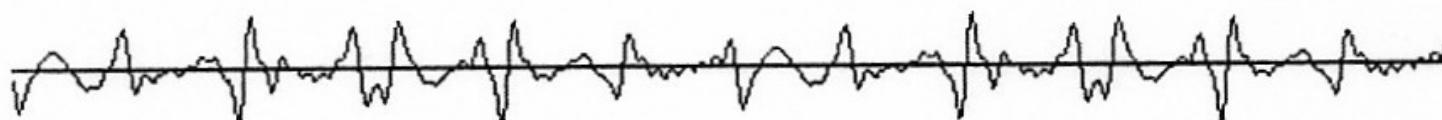
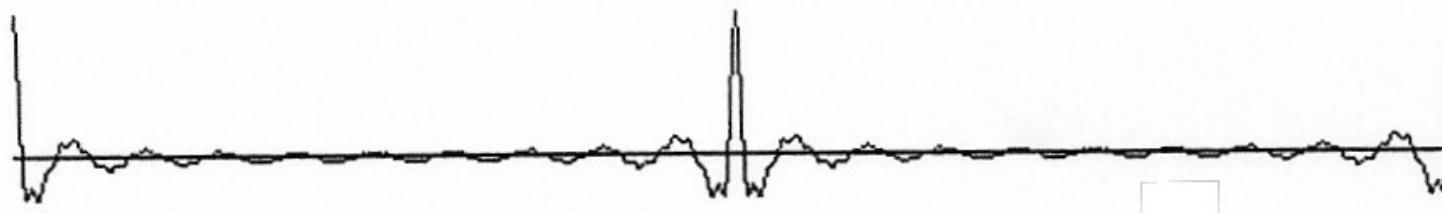
lk03\_01



# Periodiktöne nach Seebek

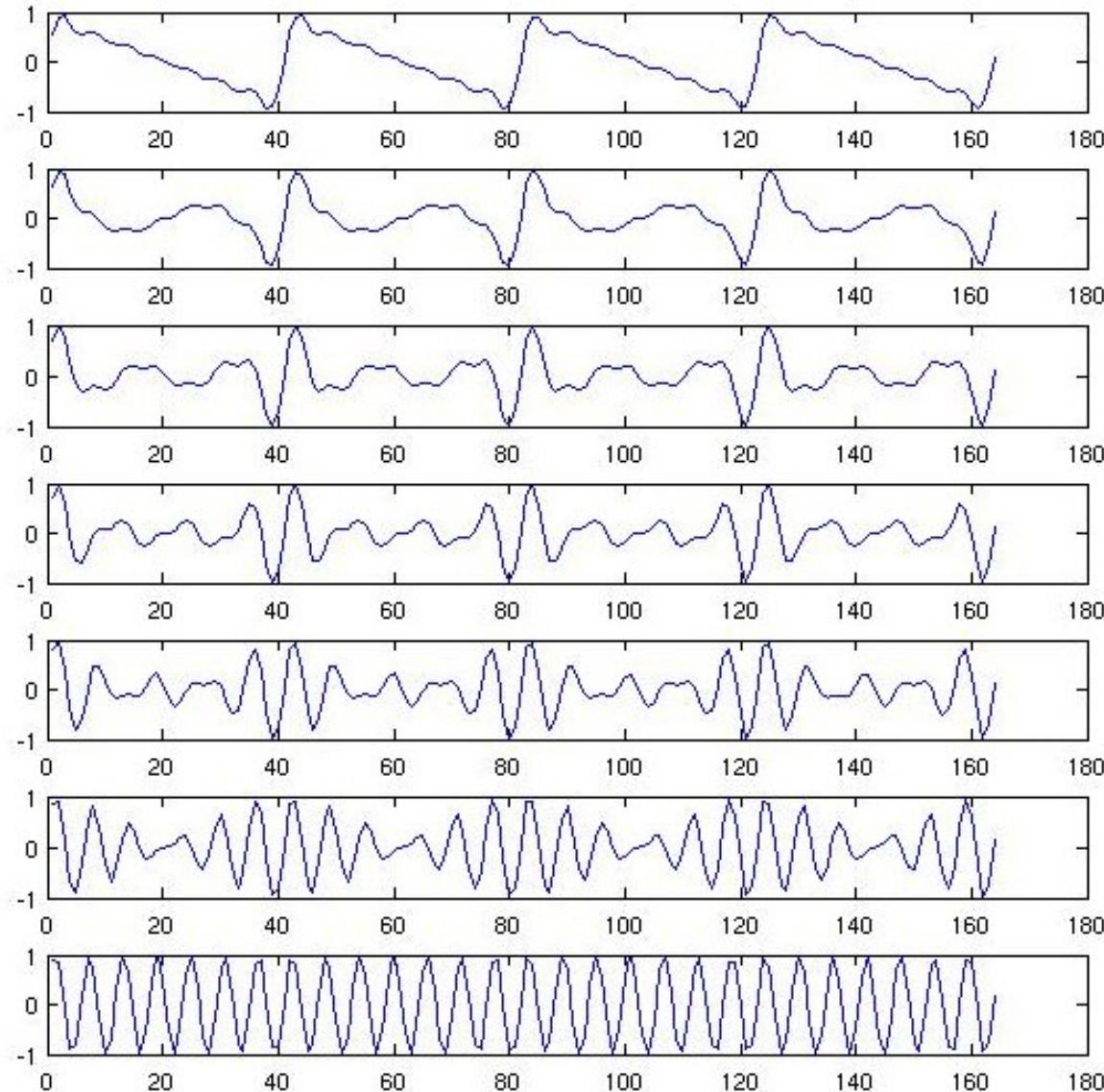


# Fehlende Teiltöne und Phase

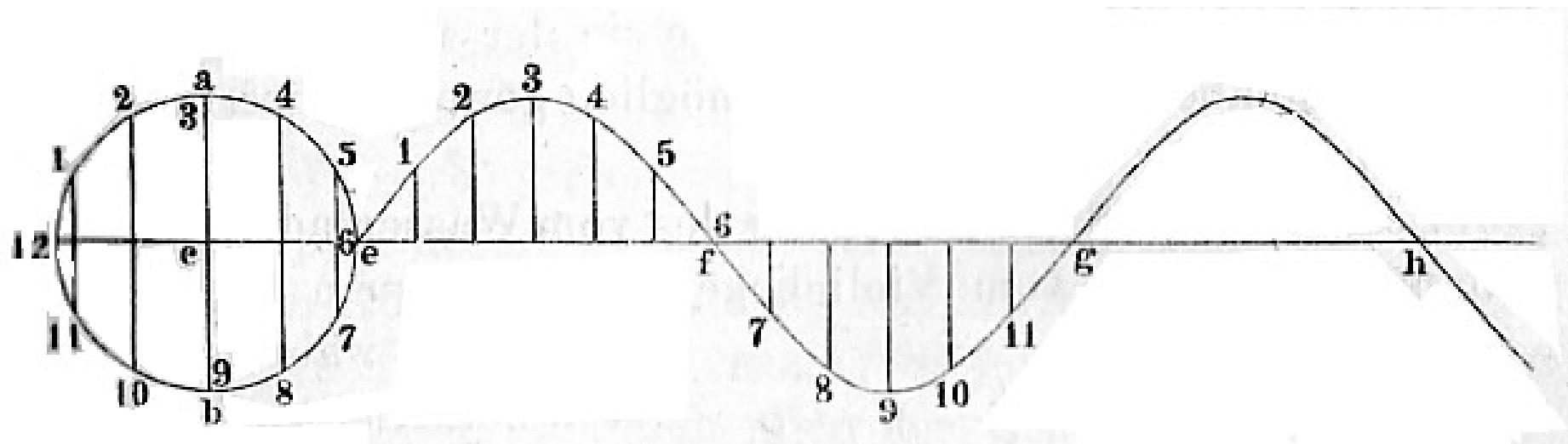


$$a_n = \frac{1}{n} \quad n = 10, 11, \dots, 50$$

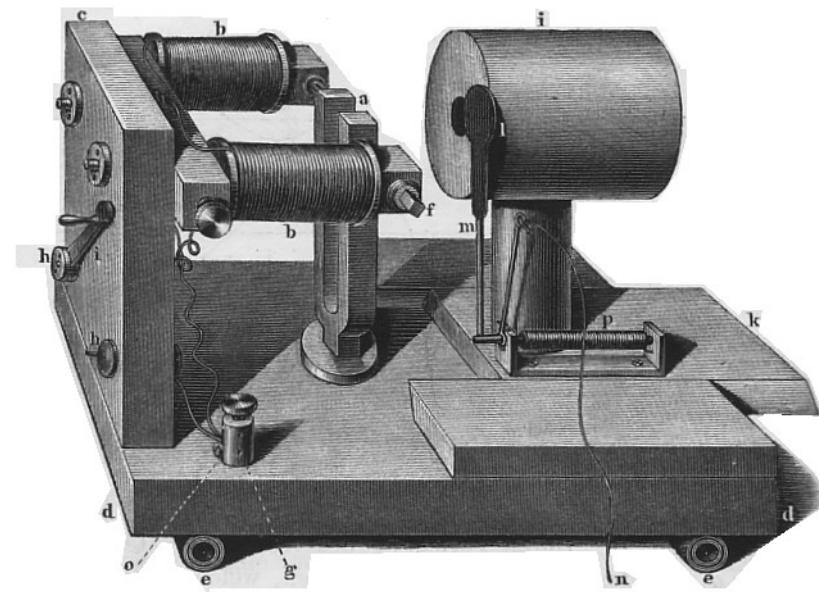
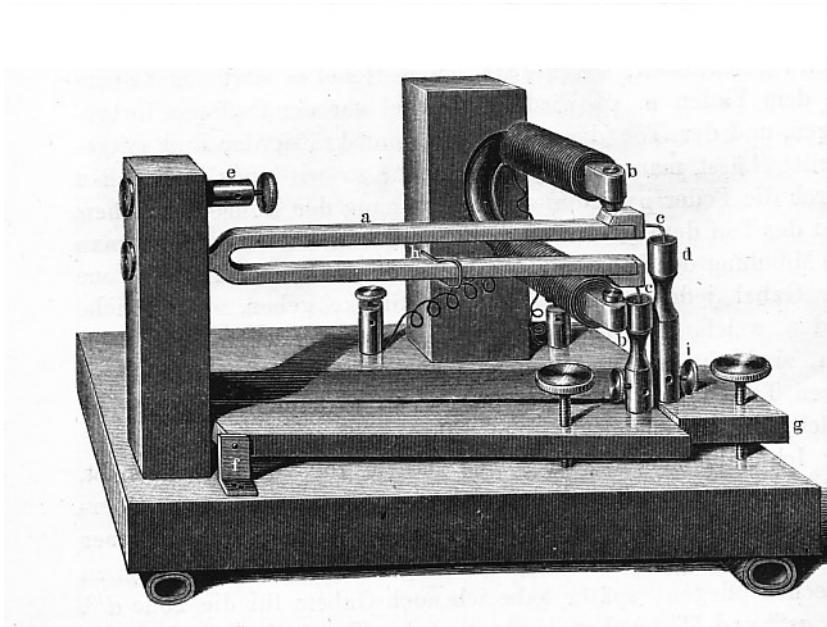
# Periodiköne



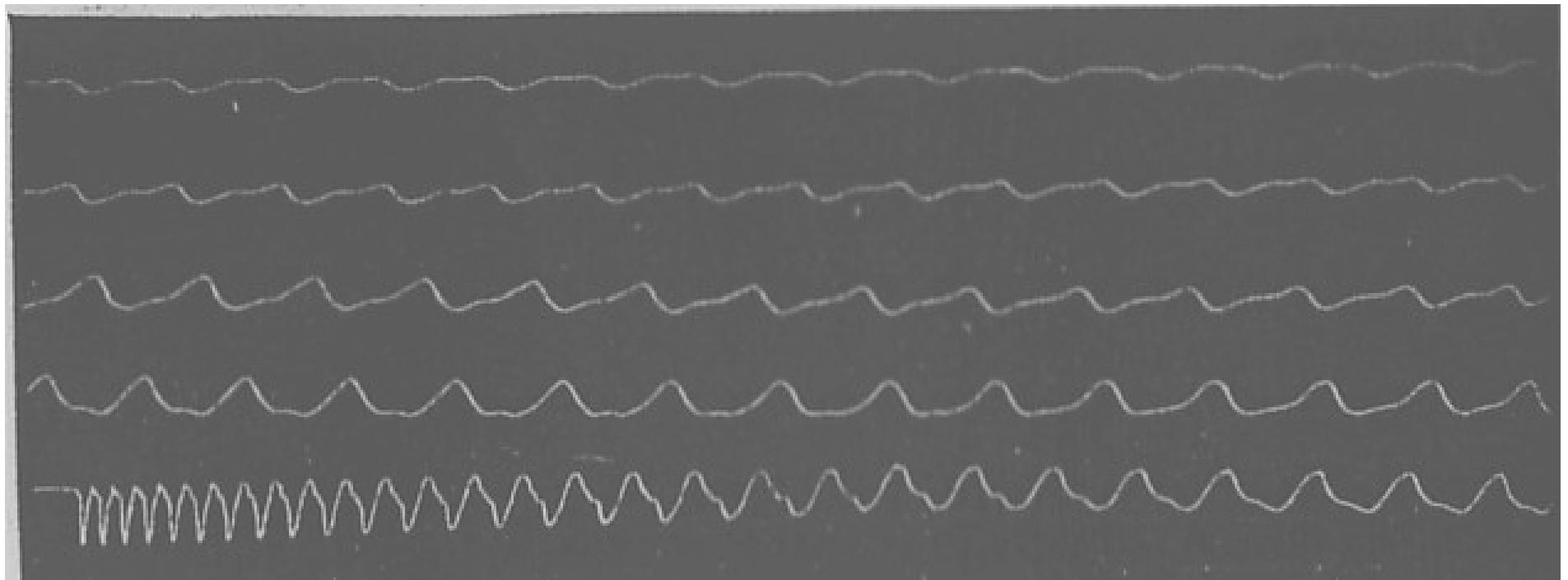
# Hermann Helmholtz 1863: Sinusschwingung und Rotation



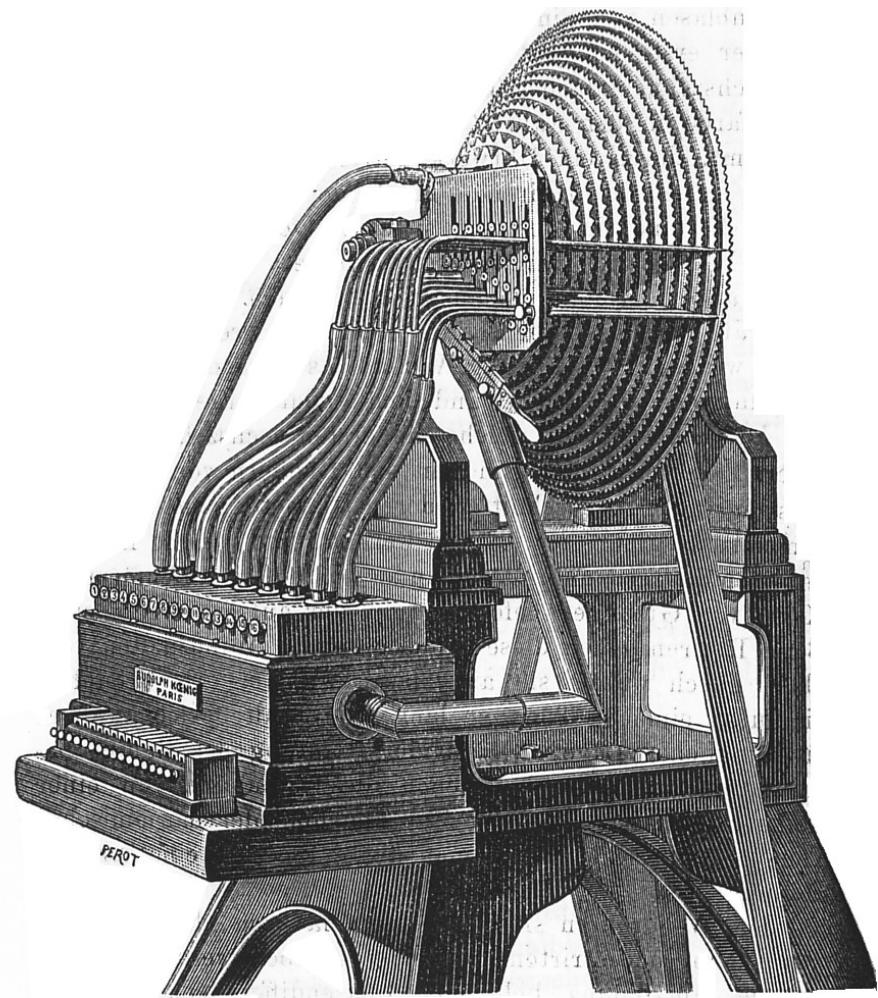
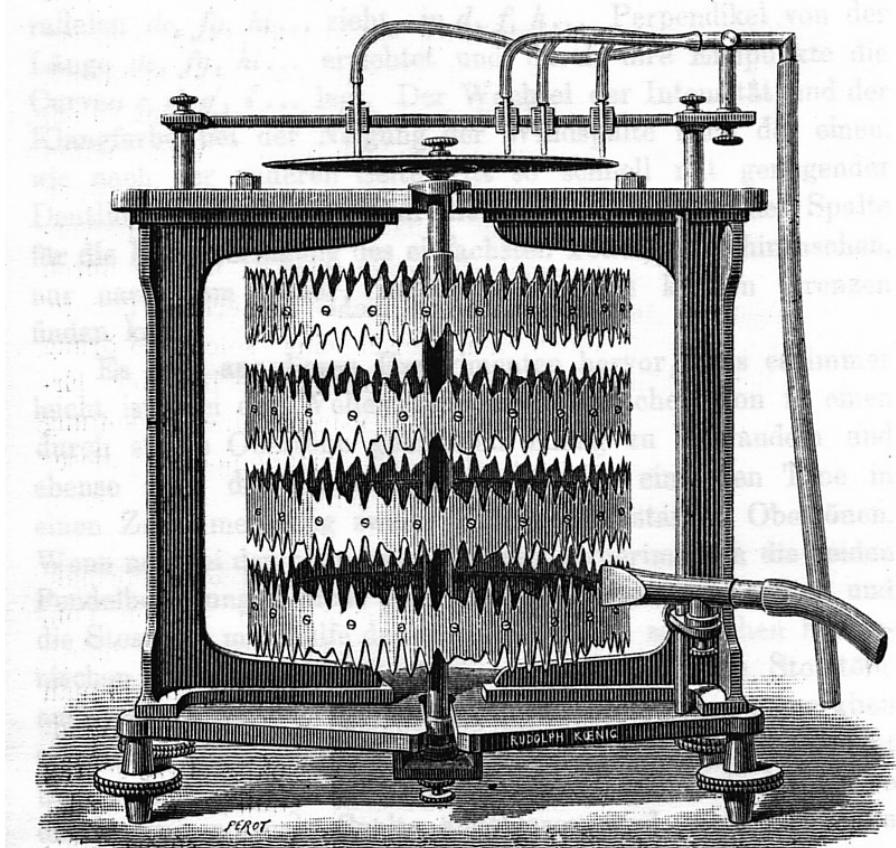
# Hemholtz: Stimmgabelsynthesizer



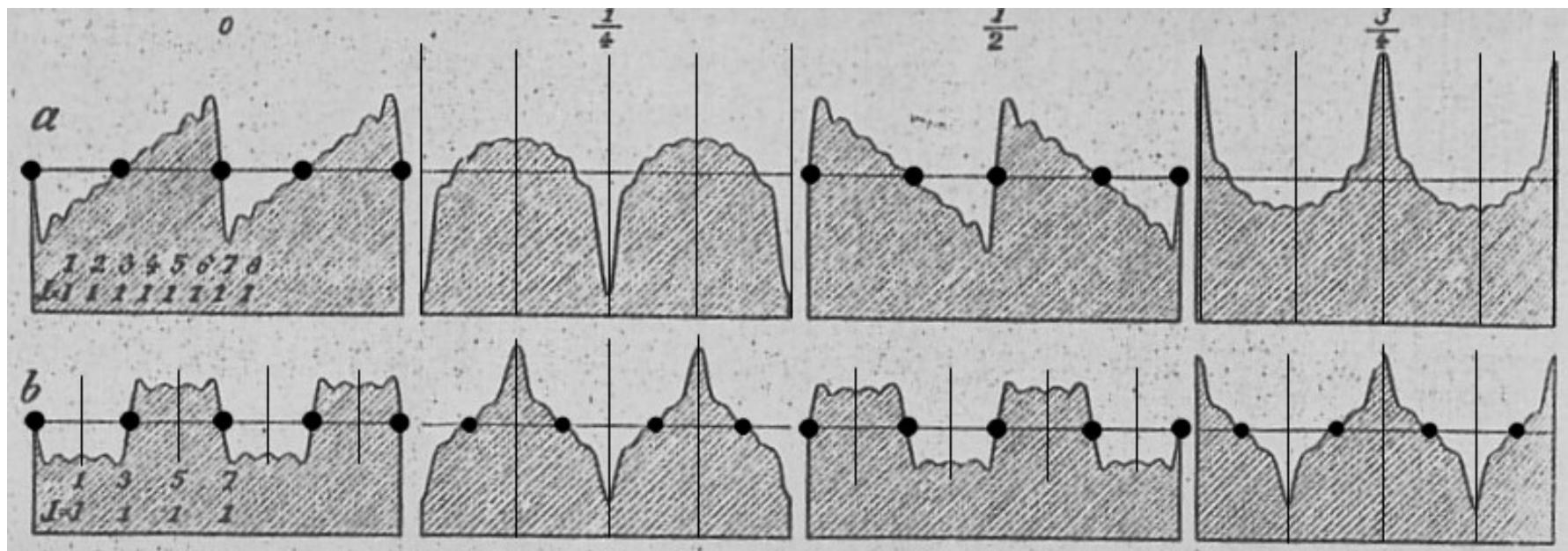
# Rudolph Koenig 1881: quasiperiodische Schwingung



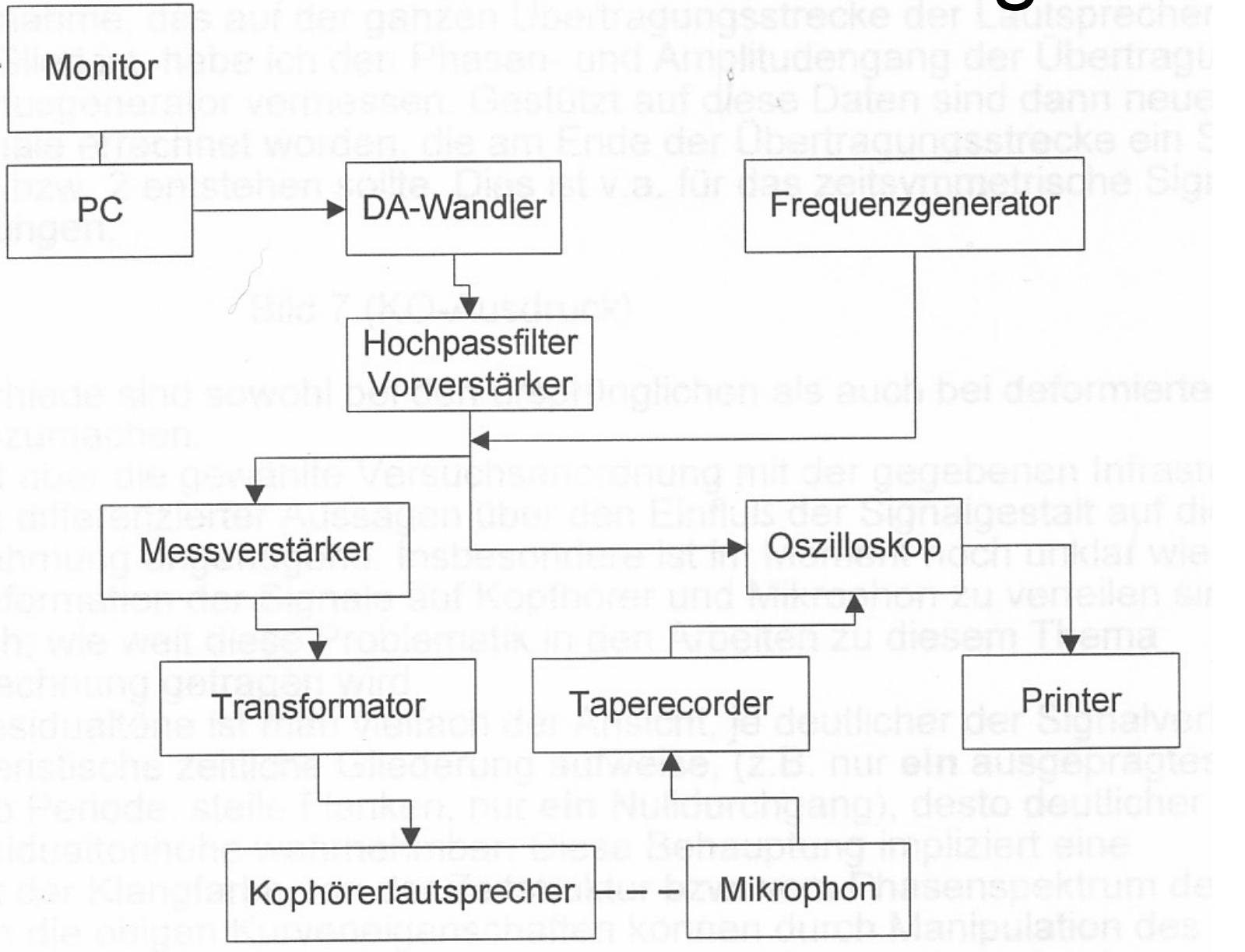
# Koenigs Synthesizer



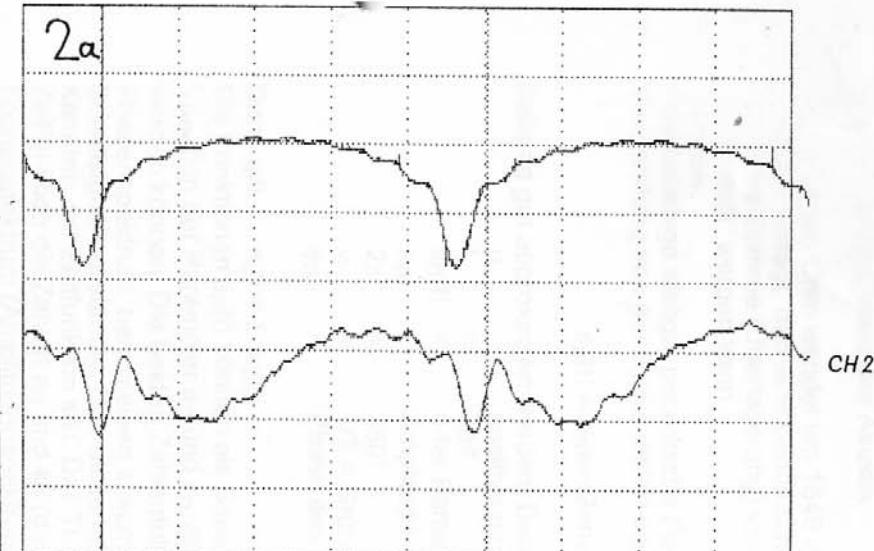
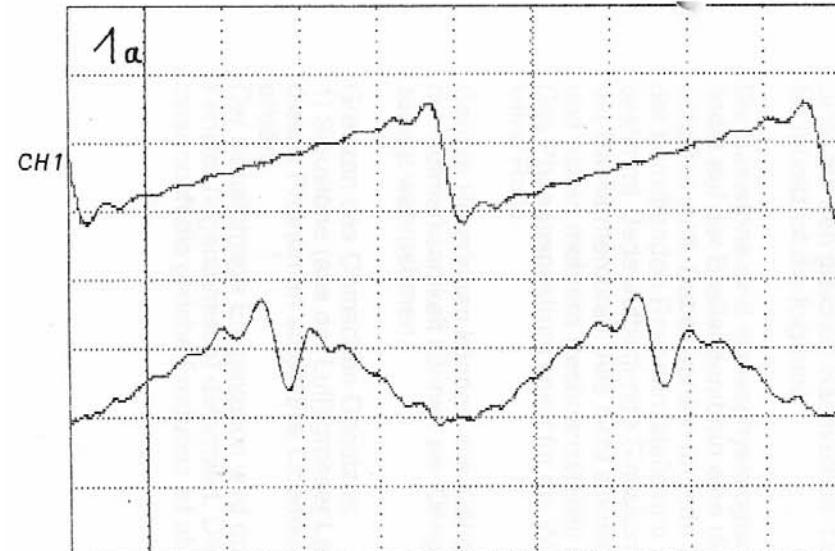
# Koenig: Periodische Klänge



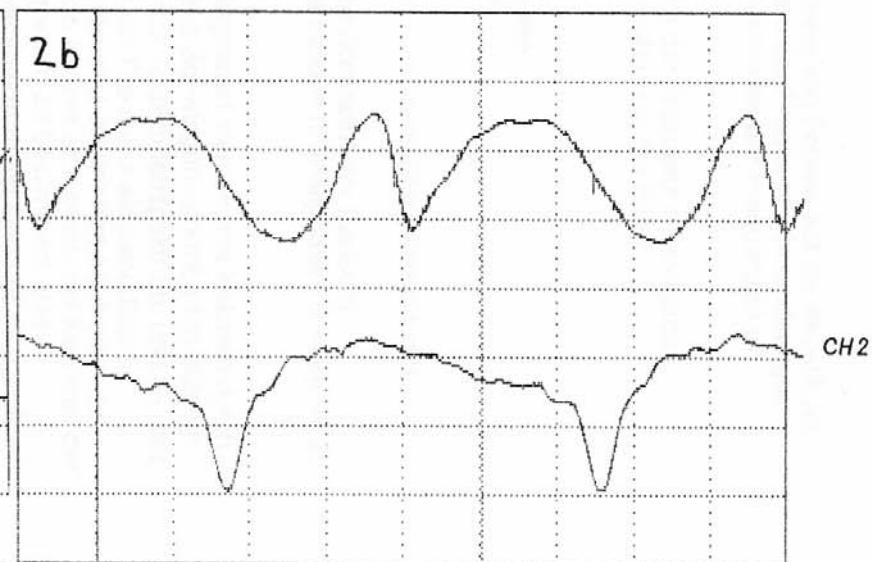
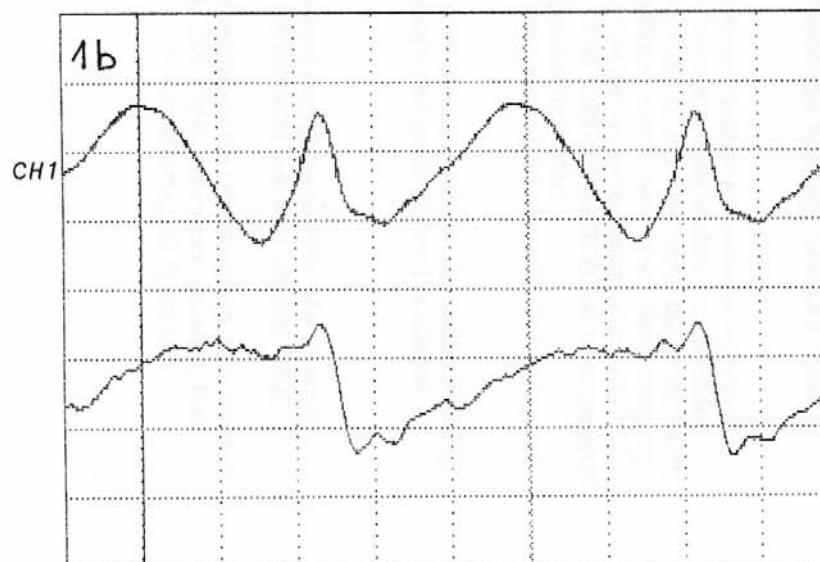
# IFI-Versuchsanordnung



# IFI-Sägezähne



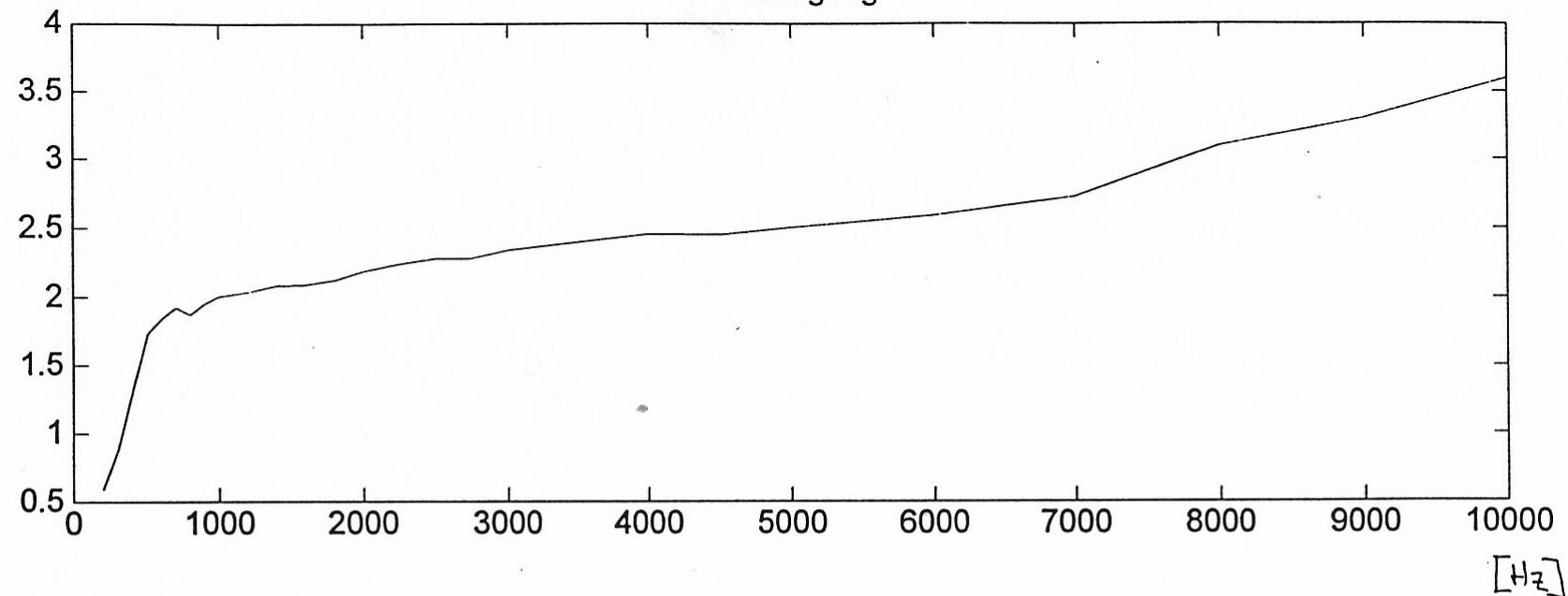
CH1>0.5V  
CH2>0.1V  
E0=0.5ms  
T1 AUTO  
PT0%  
dt 2.502ms.



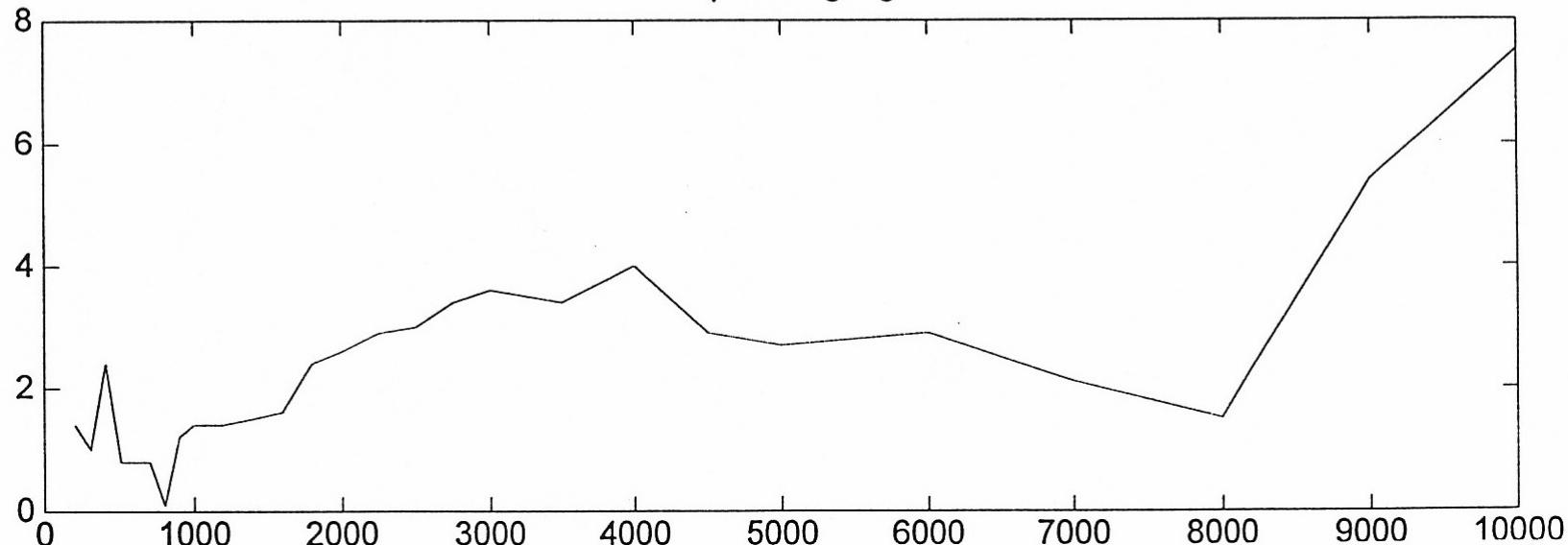
CH1>0.5V  
CH2>0.1V  
E0=0.5ms  
T1 AUTO  
PT0%  
dt 2.502ms

# IFI-Amplituden- und Phasengang

Phasengang



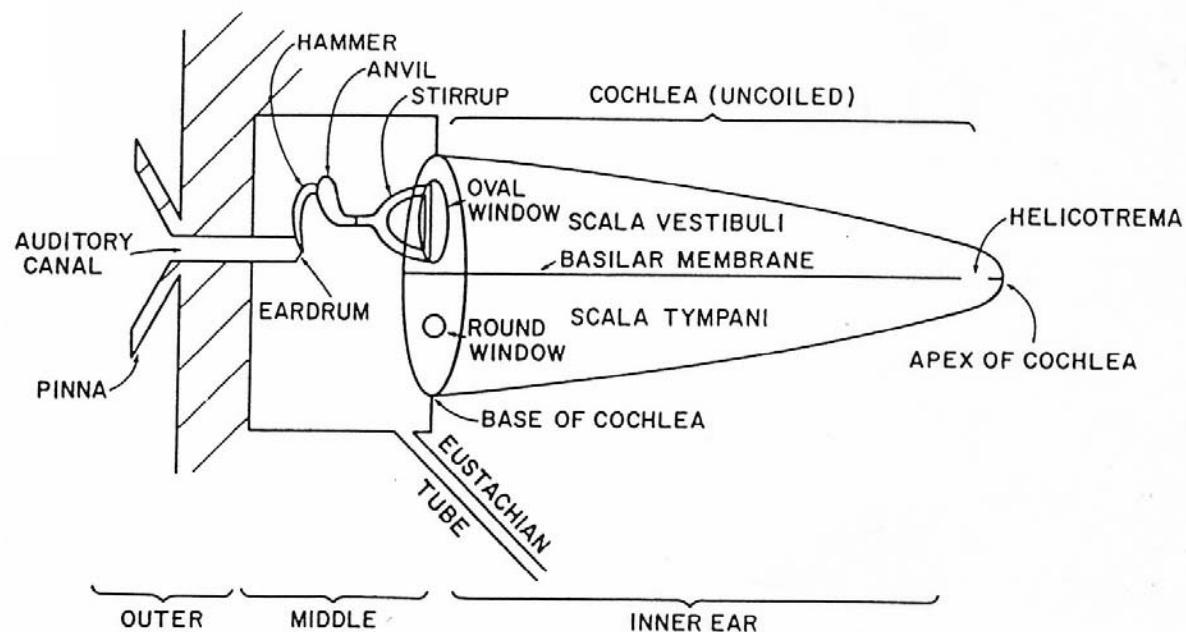
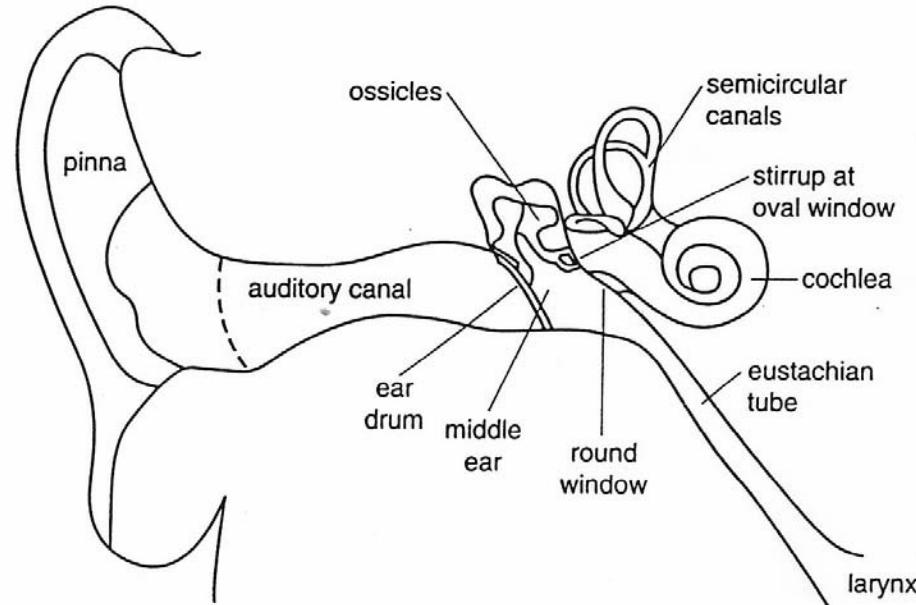
Amplitudengang



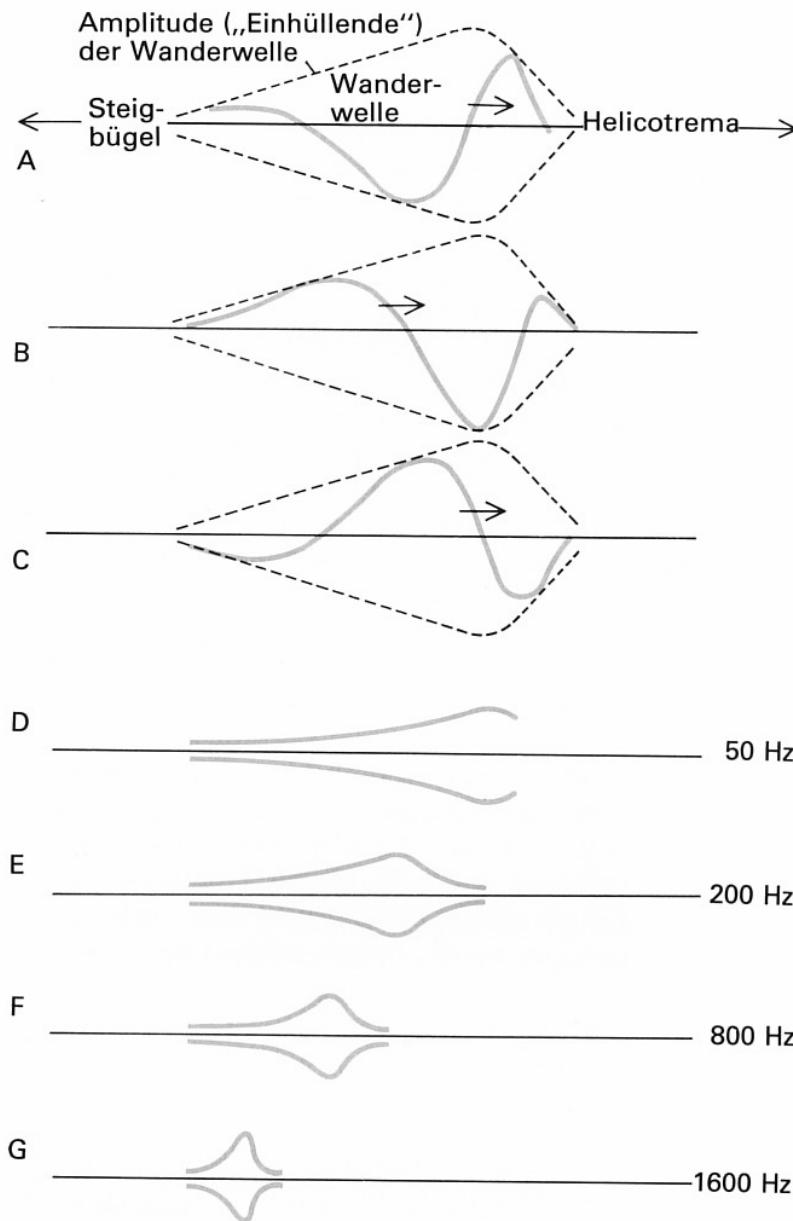
# Grenzen des Ohm'schen Gesetzes

- Kombinationstöne (Hällstöm/Ohm)
- Schwebungen (Sauveur, Smith, Young, Helmholtz)
- Schwebungen höherer Ordnung (Smith, Koenig, Thomson)
- Subjektive Obertöne (Helmholtz)
- Residualtöne (Seebeck, Koenig, Schouten)

# Das periphere Hörsystem

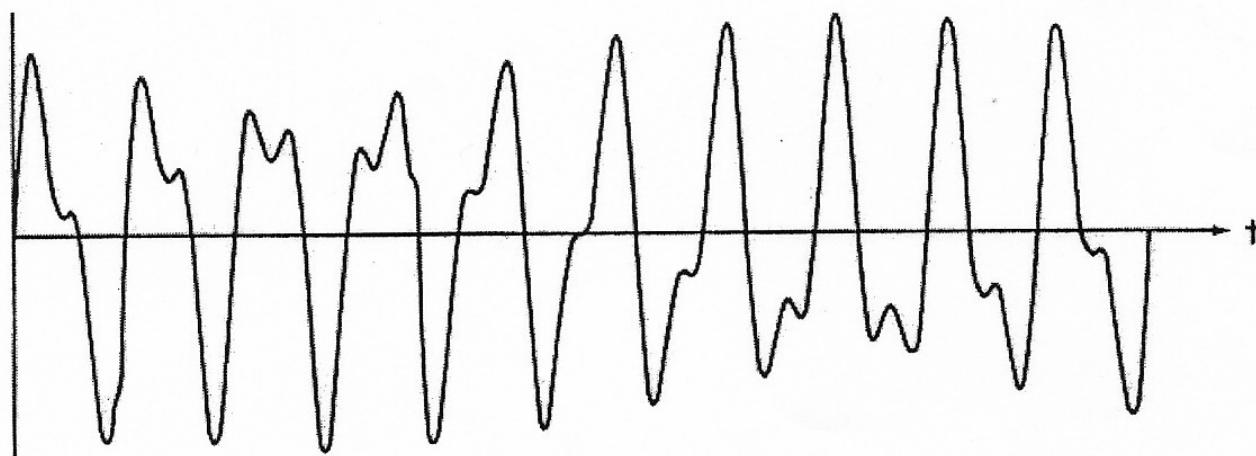
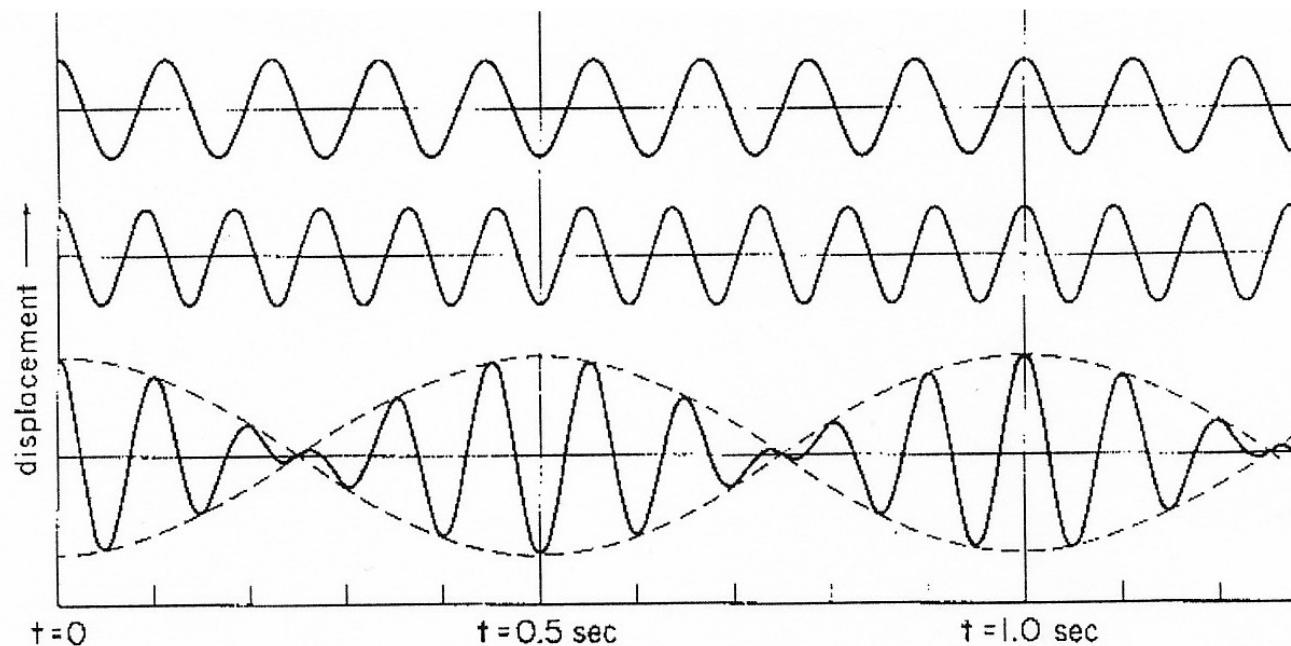


# Békésy 1947: Mechanik der Basilarmembran

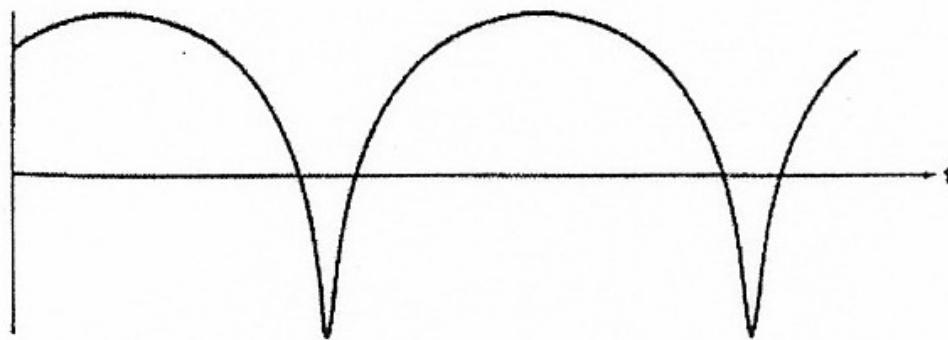
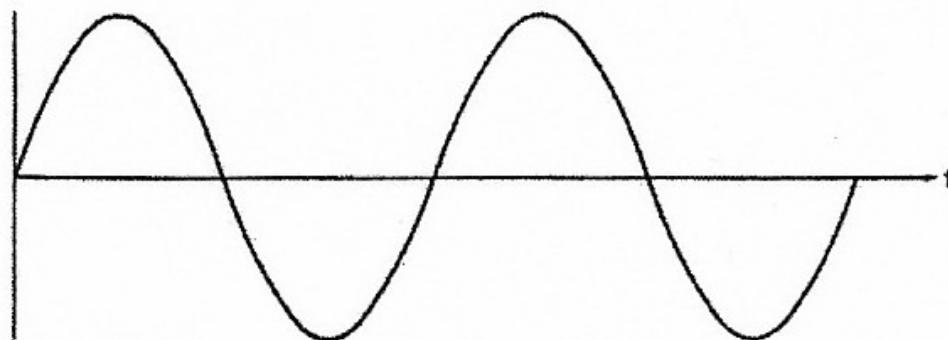


[Pierce 1989]

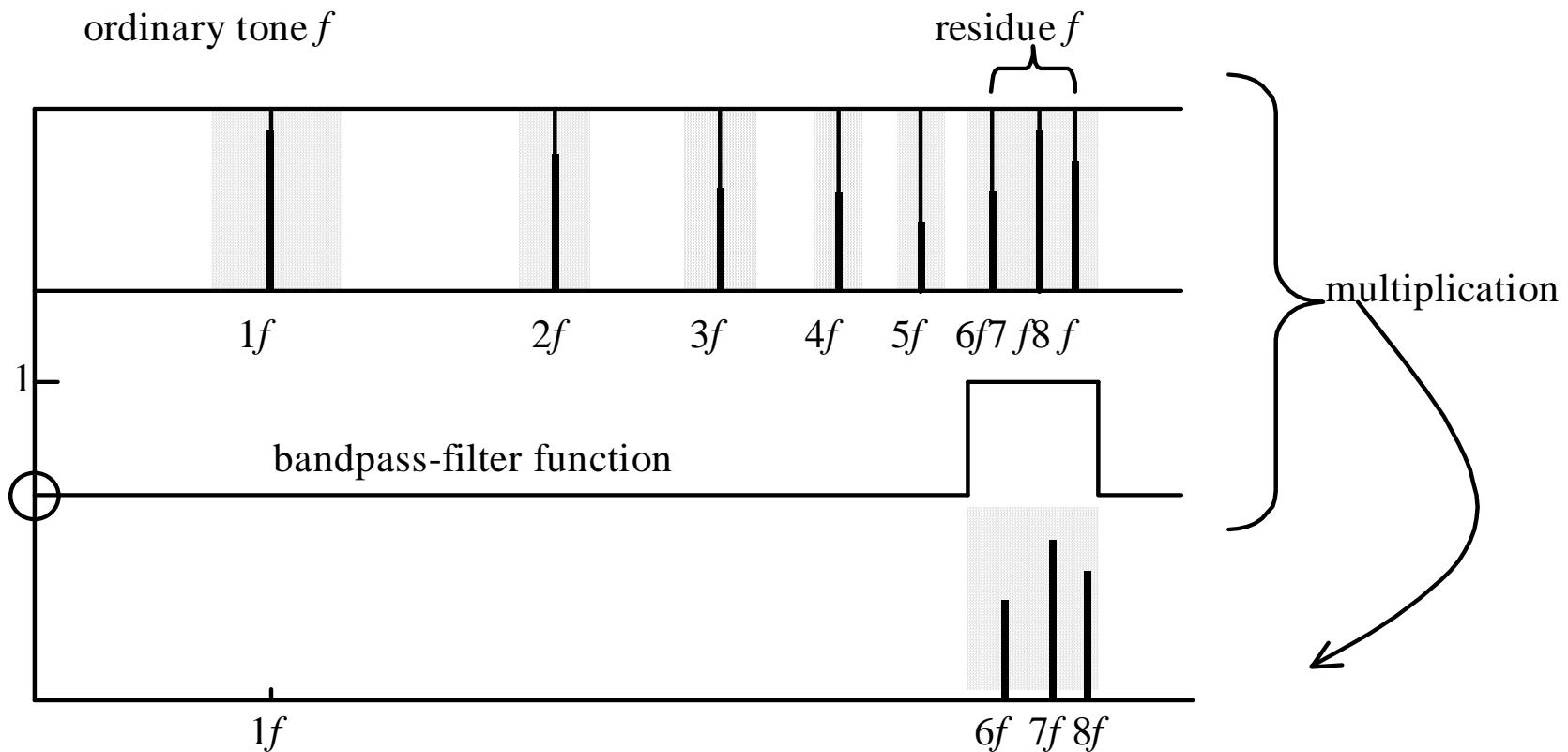
# Schwebungen



# Subjektive Obertöne (aural harmonics)

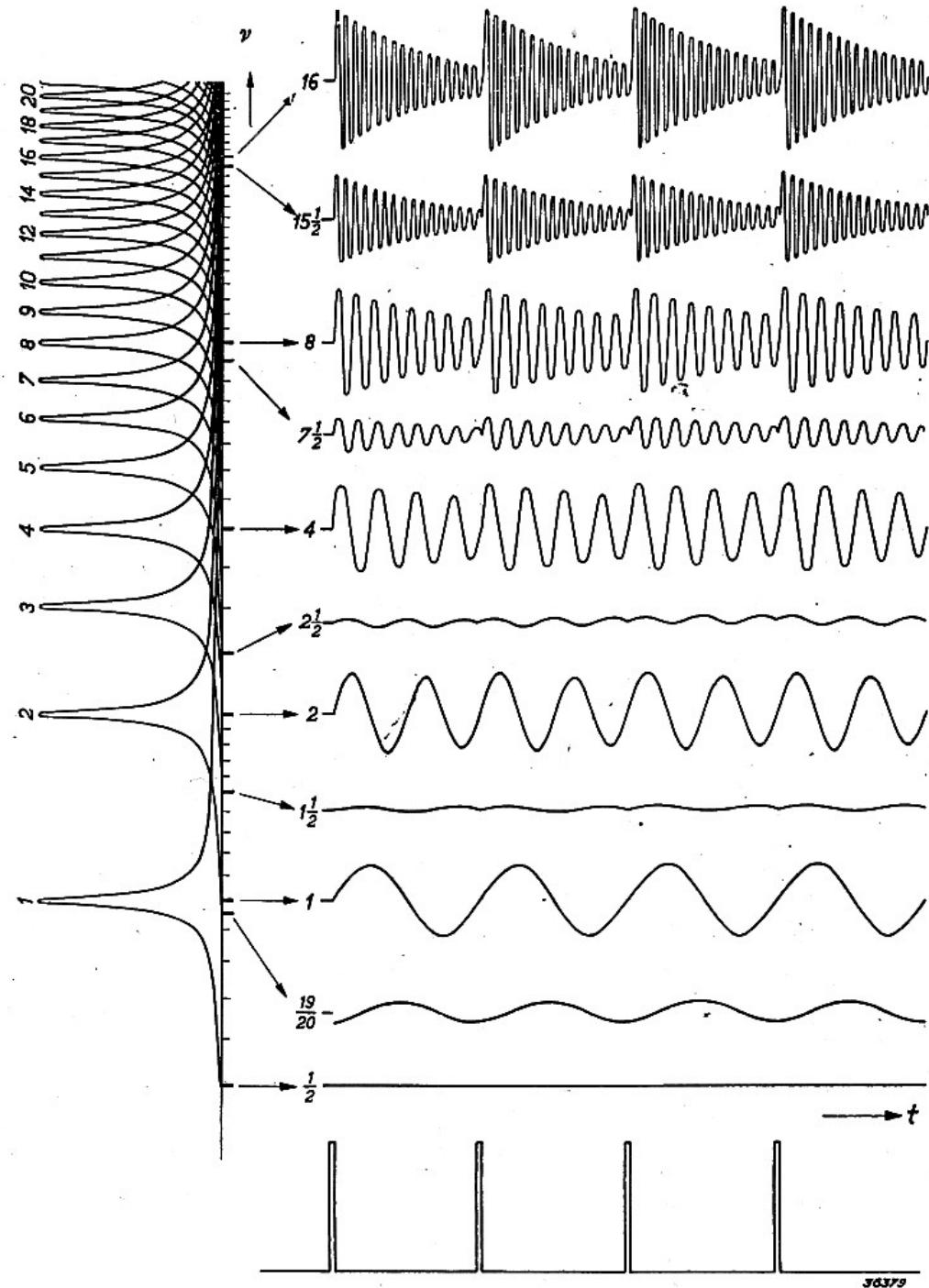


# Residualtöne

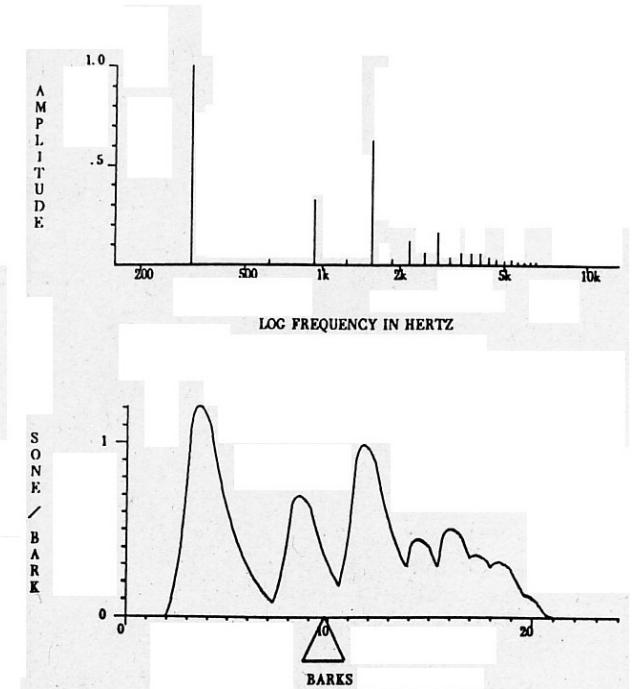
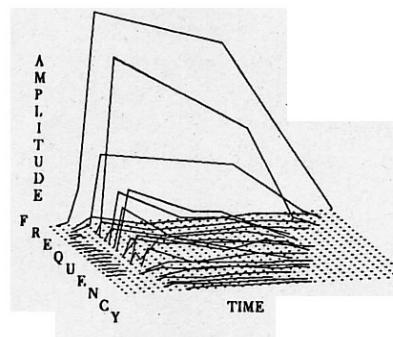
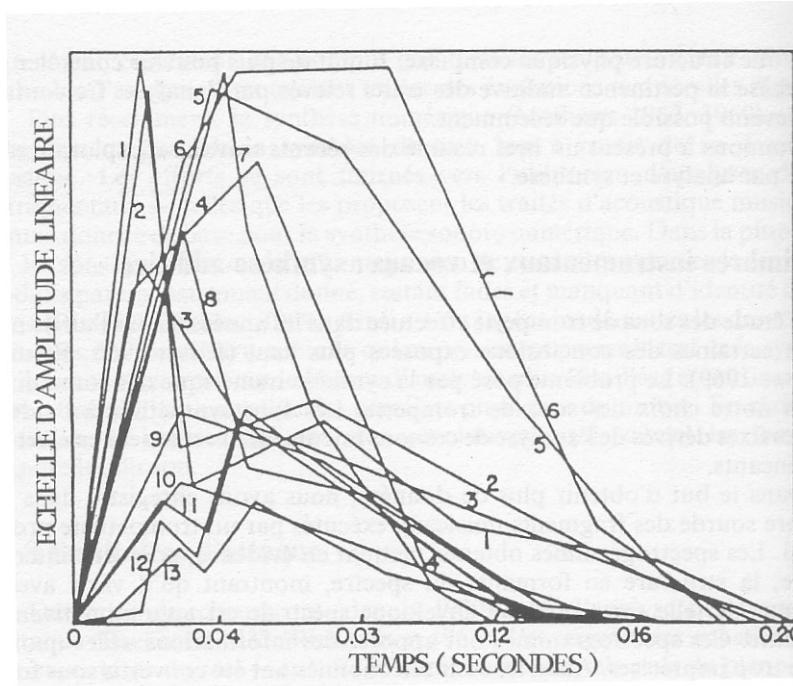


# Schouten 1940

Das Gehör als Filterbank



# Der Ton als Landschaft



Risset & Mathews 1969

Grey 1975