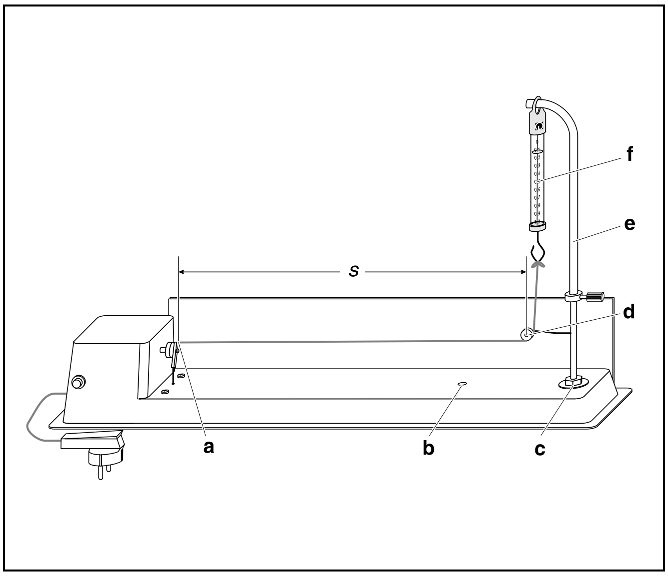
Investigating circularly polarized thread waves in the experiment setup after *Melde*

Objects of the experiment

- Generating standing, circularly polarized thread waves for various tension forces *F*, thread lengths *s* and thread densities *m**.
- Determining the wavelength λ of thread waves as a function of the tension force *F*, the thread length *s* and thread density *m**.

Fig. 1 Arrangement for the experiment after *Melde*
(a) Cam
(b) Mounting point for thread length s = 0.35 m
(c) Mounting point for thread length s = 0.48 m
(d) Deflection pulley
(e) Holding arm
(f) Dynamometer



Principles

The propagation speed of a wave in a medium is calculated using *d'Alembert's* wave equation. For an elastically tensioned thread, we compare e. g. the restoring force acting on a section of the thread deflected from its resting position with the inertial force of this piece of thread. The result for the propagation speed is

$$c = \sqrt{\frac{F}{A \cdot \rho}} \qquad \text{(I)}$$

(F = tension force, A = thread cross-section, ρ = density of the thread material)

Thus, at a fixed excitation frequency f, the following applies for the wavelength λ:

$$\lambda \sim \sqrt{\frac{F}{m*}} \quad \text{mit } m* = \frac{m}{s} \qquad \text{(II)}$$

(m = mass of thread, s = thread length).

In the experiment arrangement after *Melde*, standing, circularly polarized waves are generated in a thread with known length s. The tension force F is varied until waves with the wavelength

$$\lambda_n = \frac{2s}{n} \qquad \text{(III}$$

(n = number of oscillation nodes)

are obtained. Using the measurement data obtained in this manner, it becomes possible to verify equation (II).

Setting up and carrying out the experiment

Set up the experiment as shown in Fig. 1.

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Apparatus

1 Vibrating thread apparatus	401 03
1 Tape measure, 2 m	311 77

Preparation:

- Cut up the thread supplied with the apparatus into three pieces of different lengths:
  Cut off a piece 0.65 m long as thread 1 for part a.
  Cut off a piece 0.50 m long as thread 2 for part b.
  Cut off a piece approx. 2.60 m long as thread 3, fold it over itself four times; entwine the thread pieces together and tie their ends.

Important: start each measurement with the completely detensioned thread and vary the tension by slowly and carefully changing holding arm **(e)**.

a) Wavelength λ as a function of the tension force *F*

- Set up the holding arm **(e)** of the vibrating thread apparatus at position **(c)**.
- Tie one end of thread 1 to cam **(a)**.
- Tie a loop in the other end, hang this on the dynamometer **(f)**.
- Measure the distance between cam **(a)** and the center of the deflection pulley **(d)** (= thread length *s*) and write this value in the experiment log.
- Switch on the motor of the apparatus.
- With the adjusting screw loosened, vary the force *F* by changing the height of the holding arm **(e)** until a standing wave of maximum amplitude with the wavelength λ = 2 s is formed (one oscillation antinode).
- Read off the corresponding force F_1 and write this value in the experiment log.
- By slowly and carefully varying the height of holding arm **(e)**, determine the forces F_n at which standing waves with *n* = 2, 3, 4 and 5 antinodes are formed.
- Write down the number *n* of nodes, the corresponding force F_n and the frequency *f* in the experiment log.
- Switch off the motor.

b) The influence of thread length *s* and thread mass *m:*

- Set up holding arm **(e)** of the vibrating thread apparatus at position **(b)**.
- Attach thread 2.
- Measure the distance between cam **(a)** and the center of the deflection pulley **(d)** (= thread length *s*) and write this value in the experiment log.
- Switch on the motor of the apparatus.
- Determine the forces F_n and the frequencies *f* at which standing waves with *n* = 1, 2, 3 and 4 antinodes are formed.
- Switch off the motor.

c) Wavelength λ and phase velocity *c* as a function of the density *m*:*

- Set up the holding arm **(e)** of the vibrating thread apparatus at position **(c)**.
- Attach thread 3.
- Switch on the motor.
- Determine the forces F_n and the frequencies *f* at which standing waves with *n* = 2, 3, 4, 5 and 6 antinodes are formed.
- Switch off the motor.

Measuring example

Tables 1 a, b, and c show the measurement results for experiment parts a), b) and c).

Table 1: Tension force F_n for a standing wave with *n* oscillation nodes
a) Thread 1 with single density value, *s* = 0.48 m
b) Thread 2 with single density value, *s* = 0.35 m
c) Thread 3 with single density value, *s* = 0.48 m

	thread 1	thread 2	thread 3
n	$\frac{F}{N}$	$\frac{F}{N}$	$\frac{F}{N}$
1	0.875	0.5	
2	0.225	0.125	0.925
3	0.1	0.05	0.425
4	0.05	0.025	0.25
5	0.025		0.15
6			0.1

Evaluation and results

The values $\sqrt{F_n}$ and the wavelengths λ_n calculated from the number of oscillation nodes *n* using equation (II) are given in Table 2 a, b and c. Fig. 2 shows the corresponding graph $\lambda = f(\sqrt{F})$.

Table 2: Evaluation of the measurement results from Table 1

	thread 1		thread 2		thread 3	
n	$\sqrt{\frac{F}{N}}$	$\frac{\lambda}{m}$	$\sqrt{\frac{F}{N}}$	$\frac{\lambda}{m}$	$\sqrt{\frac{F}{N}}$	$\frac{\lambda}{m}$
1	0-94	0.96	0.71	0.70		
2	0.47	0.48	0.35	0.35	0.96	0.48
3	0.32	0.32	0.22	0.23	0.65	0.32
4	0.22	0.24	0.16	0.18	0.50	0.24
5	0.16	0.19			0.39	0.19
6					0.32	0.16

The wavelength λ_n of the threads increases with the tension force *F,* and the number of oscillation nodes *n* decreases. The graph $\lambda = f(\sqrt{F})$. shows the same slope for threads of the same density $\frac{m}{s}$ regardless of the length *s* of the thread. For threads with four times the density, the slope is half as great.

Fig. 2: Graph of $\lambda = f(\sqrt{F})$.
Circles: data from Table 2 a
Triangles: data from Table 2 b
Squares: data from Table 2 c