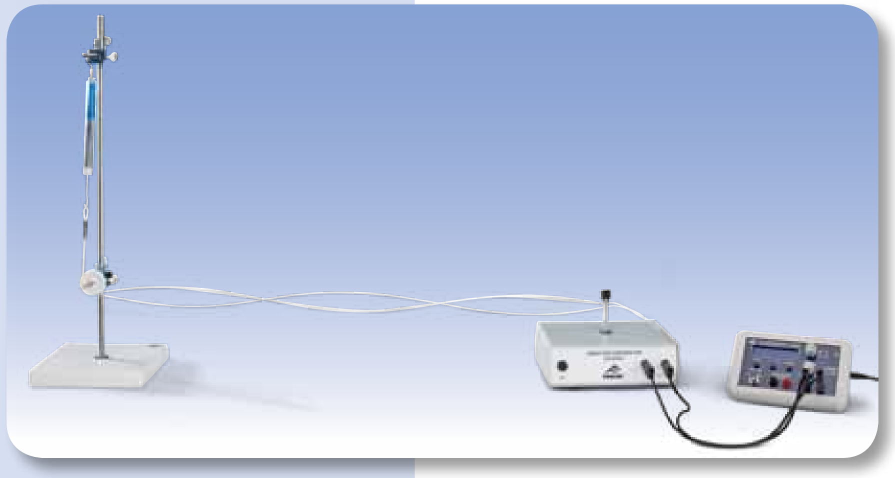
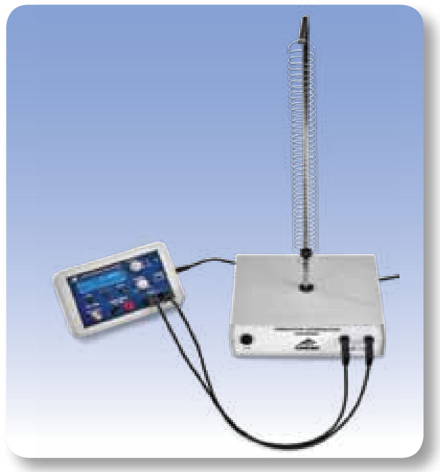
MECHANICAL WAVES





EXPERIMENT PROCEDURE

- **Generate standing longitudinal waves in a coil spring and standing transverse waves along a rope.**
- **Measure the intrinsic frequency f_n as a function of number of nodes n.**
- **Determine the corresponding wavelength λ_n and speed of propagation of the waves c.**

OBJECTIVE

Investigate standing waves along a stretched coil spring and a taut rope

SUMMARY

Some examples of where mechanical waves arise include a stretched coil spring, where the waves are longitudinal, or a taut rope where the waves are transverse. In either case, standing waves will be set up if one end of the carrier medium is fixed. This is because the incoming wave and the wave reflected at the fixed end have the same amplitude and are superimposed on one another. If the other end is also fixed, the only way that waves can propagate is if resonance conditions are met. In this experiment the coil spring and the rope are fixed at one end. The other end, a distance *L* from the fixed point, is fixed to a vibration generator, which uses a function generator to drive small-amplitude oscillations of variable frequency *f*. This end can also be regarded as a fixed point to a good approximation. The intrinsic frequency of the vibration will be measured as a function of the number of nodes in the standing wave. The speed of propagation of the wave can then be calculated from this data.

REQUIRED APPARATUS

Quantity	Description	Number
1	Accessories for Spring Oscillations	1000703
1	Accessories for Rope Waves	1008540
1	Vibration Generator	1000701
1	Function Generator FG 100 (230 V, 50/60 Hz)	1009957 or
	Function Generator FG 100 (115 V, 50/60 Hz)	1009956
1	Precision Dynamometer, 2 N	1003105
1	Pocket Measuring Tape, 2 m	1002603
1	Pair of Safety Experimental Leads, 75 cm, red/blue	1017718

BASIC PRINCIPLES

Some examples of where mechanical waves arise include a stretched coil spring or a taut rope. The waves arising in the spring are longitudinal waves since the deflection of the coil is in the direction of propagation. The waves along a rope by contrast are transverse waves. This is because the incoming wave and the wave reflected at the fixed end have the same amplitude and are superimposed on one another. If the other end is also fixed, the only way that waves can propagate is if resonance conditions are met.

Let $\xi(x,t)$ be the longitudinal or transverse deflection at a point *x* along the carrier medium at a point in time *t*. The following is then true:

(1) $$\xi_1(x,t) = \xi_0 \cdot \cos(2\pi \cdot f \cdot t - \frac{2\pi}{\lambda} \cdot x)$$

This applies to a sinusoidal wave travelling from left to right along the carrier medium. The frequency *f* and wavelength λ are related in following way:

(2) $$c = f \cdot \lambda$$

c: Propagation velocity of wave

If such a wave, travelling from left to right, should be reflected from a fixed point at $x = 0$, a wave travelling from right to left direction then arises.

(3) $$\xi_2(x,t) = -\xi_0 \cdot \cos(2\pi \cdot f \cdot t + \frac{2\pi}{\lambda} \cdot x)$$

The two waves are then superimposed to create a standing wave.

(4) $$\xi(x,t) = 2\xi_0 \cdot \sin(2\pi \cdot f \cdot t) \cdot \sin(\frac{2\pi}{\lambda} \cdot x)$$

These considerations are valid regardless of the nature of the wave or of the carrier medium.

If the other end is also fixed at a position $x = L$, then the following resonance condition needs to be fulfilled at all times *t*.

(5) $$\xi(L,t) = 0 = \sin(\frac{2\pi}{\lambda} \cdot L)$$

This only applies if the wavelength meets the following conditions:

(6a) $$\frac{2\pi}{\lambda_n} \cdot L = (n+1) \cdot \pi, \quad \lambda_n = 2 \cdot \frac{L}{n+1}$$

$$\text{or } L = (n+1) \cdot \frac{\lambda_n}{2}$$

According to equation (2), the frequency is then

(6b) $$f_n = (n+1) \cdot \frac{c}{2 \cdot L}$$

This implies that the condition for resonance (5) is only fulfilled if the length *L* is an integer multiple of half the wavelength. The resonant frequency must correspond to this wavelength. In this case, *n* is the number of nodes in the oscillation. This is zero if there is only one anti-node in the fundamental oscillation (see Fig. 2).

In this experiment, the carrier medium is either a spring or a rope which is fixed at one end. The other end is connected to a vibration generator at a distance *L* from this fixed point. This uses a function generator to drive small-amplitude oscillations of variable frequency *f*. This end can also be regarded as a fixed point to a good approximation.

EVALUATION

If resonant frequency is plotted against the number of nodes, the points will all lie along a straight line of gradient

$$\alpha = \frac{c}{2 \cdot L}$$

Therefore, as long as the length *L* is known, it is possible to calculate the speed of propagation of the wave *c*. With all other parameters being equal it is dependent on the tensile force *F*, as Fig. 5 demonstrates for the waves along the rope.

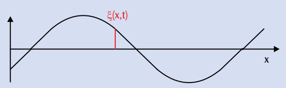


Fig. 1: Illustration of how the localised deflection $\xi(x,t)$ is defined

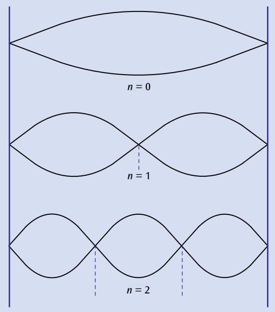


Fig. 2: Standing waves

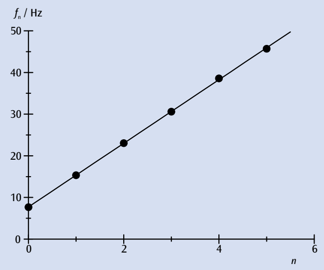


Fig. 3: Resonant frequency as a function of the number of nodes for waves along a coil spring

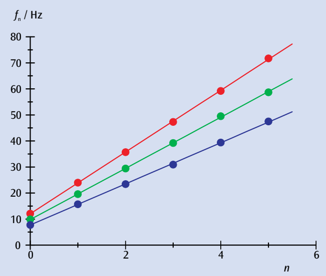


Fig. 4: Resonant frequency as a function of the number of nodes for waves along a rope

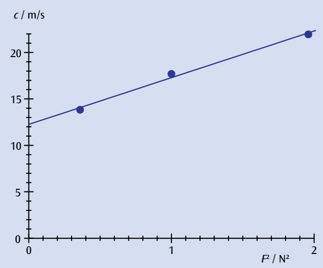


Fig. 5: Wave velocity *c* as a function of F^2 for the waves along a rope