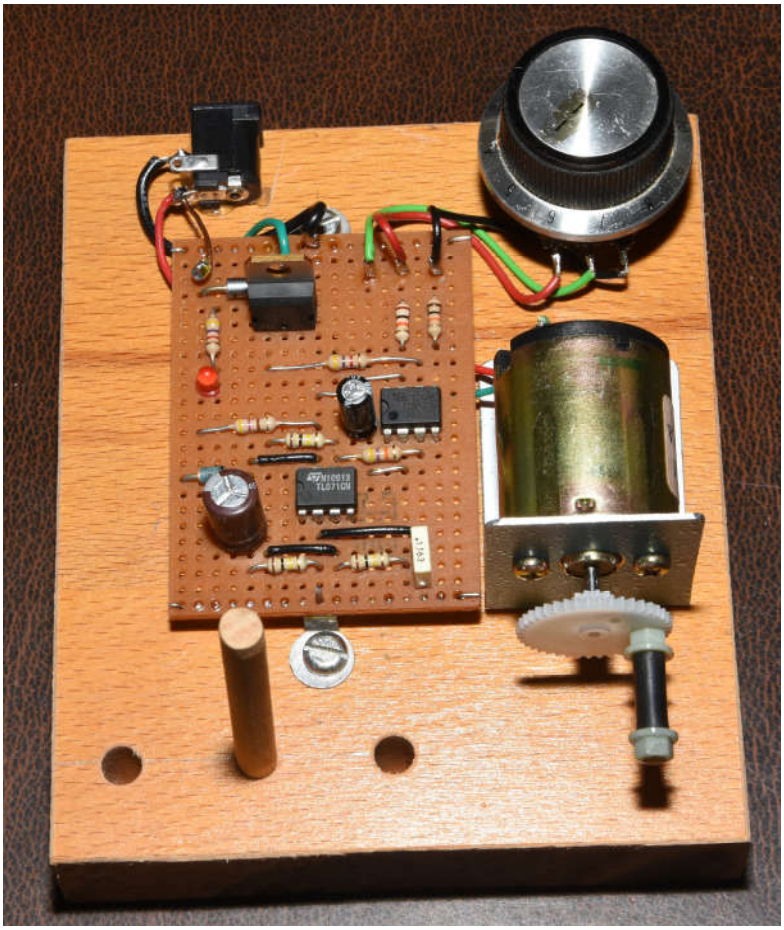
Melde's Experiment.

In 1859, the German physicist, Franz Melde, investigated stationary waves on a string.
Melde originally used a tuning fork to vibrate the string, and most modern demonstrations of this experiment use an electromagnetic piston (vibrator).
Many small electric motors will rotate at speeds of up to ~10,000 revolutions per minute (rpm), which corresponds to a frequency of ~ 170Hz
These motors can also be persuaded to rotate at low speeds by powering them with voltage pulses rather than a steady voltage. Such motors can readily vibrate a string to produce stationary waves.

Equipment.



There is nothing that is critical with the design of this equipment and can be changed and experimented with depending on the resources available.

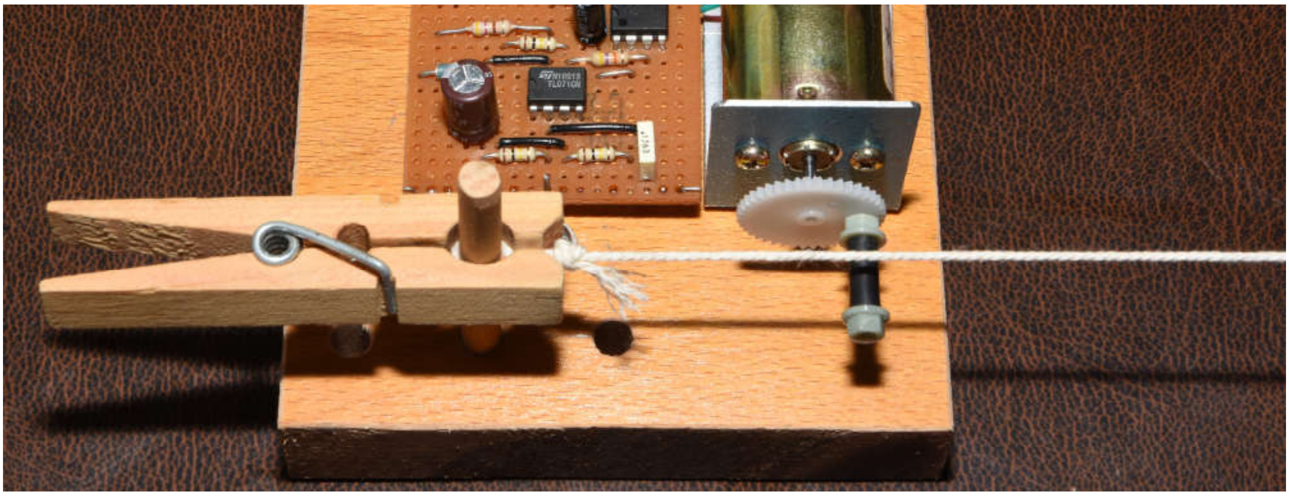
The photograph opposite shows the original motor vibrating board.
The motor was mounted on an aluminium bracket, though a wooden one would have been just as suitable.
(Or even Blu-Tac on a wooden block!)

The motor was liberated from an old toy but most small motors will be suitable.
(A new motor e.g. 37-0144 from Rapid Electronics would be suitable.)

The part that vibrates the string was made from a 22mm gear.
A 3mm hole was drilled near to the edge of the gear and a 3mm nylon bolt was secured to the gear. Insulation from a piece of mains cable was used to cover the thread of the bolt.
The gear could be replaced by a wooden disc (or cardboard) and the bolt by a piece of cocktail stick glued in place.

The circuit board is the speed controller (model train speed controller - (http/www.ikes.16mb.com/circuit/Train_Speed_Controller.pdf) but could be replaced by three AA cells, with the motor operating from one, two or three cells.

The original speed controller was powered by a 12V battery which provided 12V pulses to the motor. This did abuse the motor a little (rated 3 - 6V) but provided good slow running of the motor.



The photograph above shows how the string was attached to the motor vibrating board. A loop was tied into the end of the string and then passed over the wooden peg, secured in place by the clip-peg. The position of the string should be so that the nylon bolt (just) hits the string when it is at the top of its rotation. The more the bolt touches the string, the larger the vibrations, but the more difficult the motor has turning slowly.

The photograph opposite shows the pulley system for the other end of the string. It was made from two pieces of wood glued to a base, with a nail passing between over which the string hung. The gap in the base was for the string to hang through.
This end of the string has small masses attached to the string to keep it taught (up to ~ 100g).
The equipment should be set up on a dark surface with the pulley system hanging over the edge of the surface. A desk, table or even kitchen work surface works well.
1.5m of thin string makes a good length of string to start with, where the distance between the motor vibrating board is around 1m and 0.5m hangs over the edge of the surface.
The motor and pulley boards can be prevented from slipping on the surface by using small pieces of 'Blu-tac' underneath the boards.

Stationary Waves.

When the nylon bolt hits the string, a wave is sent along the string to the pulley. When it reaches the pulley it is reflected back along the string. If the reflected wave reaches the motor just as the bolt hits the string again, it will be again reflected and will add to the new wave travelling along the string, so producing a larger wave. As this process continues a very large deflection in the middle of the string forms, with little deflection occurring at the end of the ends of the string, and the whole 'wave' appears to be stationary.

The large deflection in the middle of the string is called an **antinode** and the regions at the ends of the string, where there is little deflect, are called **nodes**.
This will only occur at one frequency of vibration, and is known as the **fundamental frequency**.
The distance between two nodes corresponds to half of the wavelength of the wave.

If the motor rotates at two times the speed for the fundamental, then two antinodes are produced. Since this is at twice the frequency of the fundamental, it is known as the **second harmonic** frequency.

If the motor rotates at three times the speed for the fundamental, then three antinodes are produced. Since this is at three times the frequency of the fundamental, it is known as the **third harmonic** frequency.

By making the motor rotate even faster, other harmonic wave patterns can be produced and it may be possible to produce as many as 10 antinodes or even more on the string.