Resonance – Standing Waves in a Wire

**Apparatus:**
Figure 1 is a diagram of the apparatus set up. The Computer generates an audio frequency through a virtual instrument called “continuous sound output” controllable by virtual dials on the screen. This sine wave frequency outputs through the speaker, (headphone) jack. This output is connected to the input of the round hemispherical shaped audio amplifier whose output is connected through a resistor and ac ammeter to the copper wire. The magnet is set near one end of the wire. Weights are hung at the pulley end to establish the tension in the wire.

![Figure 1](image1)

**Explanation of the Apparatus:**
A current carrying wire in a magnetic field has a force exerted on it as follows:
A current exists at right angle to a magnetic field. Then a magnetically induced force exists at right angles to both current and magnetic field as shown in Figure 2.

![Figure 2](image2)

If the magnetic field is constant and the current in the wire is a sine wave periodic in time with frequency, f, then the wire has a force exerted at the magnetic field which is also in the form of a periodic sine wave. If the frequency of this applied force is at one of the natural modes of oscillation of the string, the string will respond with a resonant vibration.
The wire has a mass density, $\mu$, of 0.000886 kg/m. The tension, $T$, in the string is (neglecting friction in the pulley) equal to the mass hanging on the string multiplied by 9.8 N/kg (i.e. $9.8 \times$ mass (in kg) (= Newtons). The transverse wave velocity, $v_t$, in the string is $\sqrt{\frac{T}{\mu}}$ in (m/s). The wavelengths, $\lambda_n$, of the resonant standing waves are $2L/n$, where $L$ is the effective length of the string between the pulley and the hook at the other end. $n$ is a whole number (1, 2, 3, etc). Since the frequency equals $\frac{v_t}{\lambda_n}$, the resonant frequencies equal $n \left(\frac{v_t}{2L}\right)$ or $nf_1$. Thus the resonant standing waves are in the form of a harmonic sequence.

**Experiment:**
Hang a total of 900 g (i.e. 0.90 kg) on the pulley end of the string resulting in a tension, $T = 8.82$ Newtons. Using this $T$ with the given mass per length of the wire, 0.000886 kg/m, calculate the transverse wave velocity in the string. Measure the length of the string between pulley and the other end and estimate the expected wavelengths of the resonant standing waves.

The gain of the audio amplifier is increased by rotating the round top clockwise. The ac current should read between 0.2 and 0.4 amps. Now carefully adjust the output frequency from the computer around the estimated $f_1$ until the string vibrates in a single loop with noticeable amplitude. Record the resonant frequency and compare with your initial estimation. If you cannot get it to resonate at this lower frequency, calculate the 2nd harmonic and adjust the frequency until the string resonates.

Now repeat at expected higher harmonic frequencies. For each resonance, observe the number of vibrating loops, measure and record their lengths, and record the frequency for each observed resonance.

From each observed resonant frequency using the measured wavelength and frequency, calculate the transverse wave velocity, $(f_n \times \lambda_n)$ and compare with the value given by $\sqrt{\frac{T}{\mu}}$.

Answer the following two questions. How do your measured resonant frequencies compare with your calculated values? How well do the measured resonant frequencies match the requirements for a harmonic series?