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Abstract

This study was done to develop a simple and inexpensive wave driver that can be used in experiments on string waves. The wave driver was made using a battery-operated toy car, and the apparatus can be used to produce string waves at a fixed frequency. The working principle of the apparatus is as follows: shortly after the car is turned on, the wheel starts to turn at a constant angular speed. A rod that is fixed on the wheel turns at the same constant angular speed, too. A tight string that the wave will be created on is placed at a distance where the rod can touch the string. During each rotation of the wheel, the rod vibrates the string up and down. The vibration frequency of this rod equals the wheel's rotation frequency, and this frequency value can be measured easily with a small magnet and a bicycle speedometer. In this way, the frequency of the waves formed in the rope can also be measured.

Introduction

String waves are often used in teaching wave motion to students. In particular, standing waves created on a tight string fixed at both ends display the modes, the natural vibration designs. Creating a standing wave in a classroom will make it easier for students to learn wave motion. Concepts like nodes, anti-nodes, frequency and wavelength can be taught with experiments about standing waves created on a tight string. If the mass of the string's unit length and force that stretches the string are known, the wave's speed, the fundamental frequency and the harmonics can also be easily found [1–4].

To create pulses on a tight string like the ones in figure 1, a wave driver is needed. There are various wave drivers produced by the manufacturing companies that make lab equipment supplies. In many of these models, the frequency of the created waves can also be adjusted. The purpose of this study is to develop a wave driver that can be built by using simple tools and materials that can be reached by everyone.

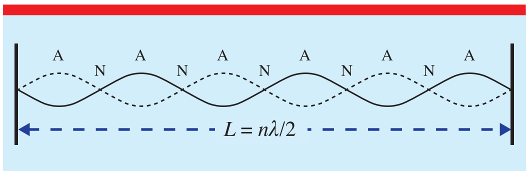

Figure 1. Standing waves formed on a string fixed at both ends.

Design and construction of the apparatus

The materials needed for the apparatus are a long, flexible elastic cord (or string), battery-operated (electric motor) toy car, a small rod, cable ties, adhesive, measuring tape, a dynamometer (or force sensor) and a bicycle speedometer (figure 2).

The rod is placed on one of the moving wheels of the toy car in the direction of the axis of rotation, as shown in figure 3. The tight string that the wave will be created on is placed at a distance where the rod can touch the string. When the car is turned on, the rod vibrates the string up and down with each rotation of the wheel. The frequency of the waves that are created by this vibration equals

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Figure 2. Materials used.

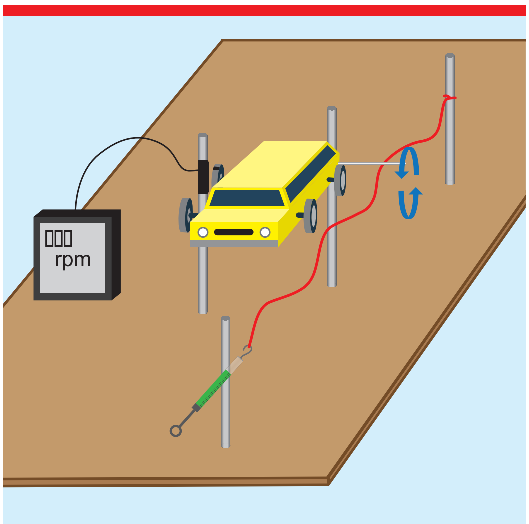

Figure 3. The experimental apparatus.

the rod's vibration frequency. In other words, the frequency of the waves equals the wheel's rotation frequency. To measure the wheel's rotation frequency, a small magnet is fastened on the toy car's wheel. This magnet stimulates the sensor of the bicycle speedometer each time the wheel turns. When the bicycle speedometer is adjusted to the frequency-measuring mode, the frequency of the wave is also measured in rpm.

The use of this practical experiment tool in creating standing string waves is explained by the experiment below.

Figure 4. Experimental apparatus.

Experiments and results

This experiment was done to create standing waves on a tight string fixed at both ends and to observe the harmonics. For the medium where the pulses in the experiment will spread, a flexible string (elastic cord) with a linear mass density of

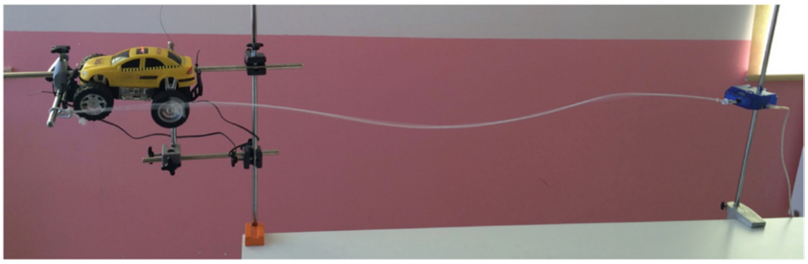

Figure 5. Standing wave formed on the string (n = 3).

Figure 6. Standing wave formed on the string (n = 5).

Table 1. The period of waves and wave sources.

n	L(m)	$\lambda = \frac{2L}{n}$ (m)	F(N)	$V = \sqrt{\frac{F}{\mu}}$ (m s^{-1})	$T_{wave} = \frac{\lambda}{V}$ (s)	f_{wheel} (rpm)	T_{wheel} (s)
1	0.44	0.886	1	18.014	0.049	1240	0.051
2	1.13	1.128	1.6	22.786	0.050	1160	0.052
3	1.74	1.157	1.7	23.487	0.049	1140	0.053
4	1.89	0.946	1.1	18.893	0.050	1181	0.051
5	2.73	1.092	1.5	22.063	0.049	1163	0.052
		Average			0.050	1165.6	0.051

μ = 3.0816 g m^{-1} was used. The apparatus shown in figure 4 is set up by tying one end of the flexible string to the force sensor (or dynamometer) and tying the other end to the side of the wave driver.

To observe various harmonics (n = 1, 2, 3, 4 and 5), the tension and the length of the flexible string are changed by moving the mechanism back and forth. When the desired harmonics are generated, the mechanism is fixed and the measurements are taken. Some of the harmonics generated in the experiment are shown in figures 5 and 6.

Sinusoidal string waves can be formed in vertical and horizontal directions by turning this apparatus. When the desired harmonics are generated, the force that stretches the string is measured with a force sensor (or dynamometer). The standing waves' speed, wavelength and period are recorded in table 1 using equations (1)–(3):

$$V = \sqrt{\frac{F}{\mu}} \tag{1}$$

$$\lambda = \frac{2L}{n} \tag{2}$$

$$T = \frac{\lambda}{V} \tag{3}$$

In this experiment, while the tension and the length of the string are changed, the wave driver is used at the same frequency all the time. All the harmonics have the same period since they are generated by the same wave driver (by the rod on the toy car's turning wheel). The average of this period is calculated as T_{wave} = 0.050. During the experiment, the rotating frequency of the toy car's wheel is measured with a bicycle speedometer for each harmonic. These measurements show that the wheel turns with average f_{wheel} = 1165.6 rpm frequency. When the rotating period of the wheel is calculated, a value very close to the waves' period was obtained.

Conclusion

In this study, an apparatus that can generate a string wave in a classroom environment using simple, cheap tools and materials is presented. The frequency of the produced waves can also be measured with a bicycle speedometer that is attached to the apparatus. With this apparatus, sinusoidal string waves can be generated in both vertical and horizontal directions. This apparatus can also help students to compare circular motion, which is a harmonic movement, to wave motion, which is also a harmonic movement. It can also be used in classroom activities to teach the concepts of frequency, period, node, anti-node, wavelength and harmonics.

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