1. Experimental Objectives

1) Learn how to measure Young's modulus using dynamic method.
2) Learn how to use an oscilloscope to observe and determine resonance of sample.
3) Learn how to determine node location through the variation of resonant peak.

2. Experimental Procedure

This apparatus provides three test samples. Experiment procedures are follows:

1) Use a ruler to measure sample length *l*; use a Vernier caliper to measure sample diameter *d* (measure 6 times at different locations and average data); and use a balance to measure sample mass *m*.

2) Estimate the resonant frequency of the sample using Eq. (20) to locate the resonant point in experiment. Materials of the three samples are brass, steel, and aluminum, respectively, whose Young's modulus are roughly $0.969\times10^{11}N/m^2$, $2.06\times10^{11}N/m^2$ and $0.7\times10^{11}N/m^2$, respectively.

3) Mount one test sample onto the vibration test platform using suspending method or supporting method. Per Fig. 5 or Fig. 6, wire the platform with the electric controller for receiver and exciter. Then wire the receiver signal (R-signal) and exciter signal (E-signal) of the electric controller to CH1 and CH2 of an oscilloscope.

4) Based on the above discussed theory for reducing measurement error (i.e. extrapolation) method, symmetrically select a few sets of excitation points and signal pick-up points with different deviation distances relative to right/left nodes of the rod while placing the receiver and exciter to the corresponding set of points.

   Note: The lengths of the three provided samples are 20 cm. There are 8 carved rings on each end of these sample bars, with distances of 1, 2, 3, 4, 4.48, 5, 6 and 7 cm from the corresponding end. Select these point pairs to suspend or support.

5) Turn on electric controller and oscilloscope. Adjust parameters of the controller until the maximum amplitude of the received resonant signal is observed on the oscilloscope. Especially, change frequency finely and slowly around the resonant frequency point.

Record the distances of the receiver and the exciter from the rod ends, and the frequency reading. An example of signal on oscilloscope is shown in Figure 7.

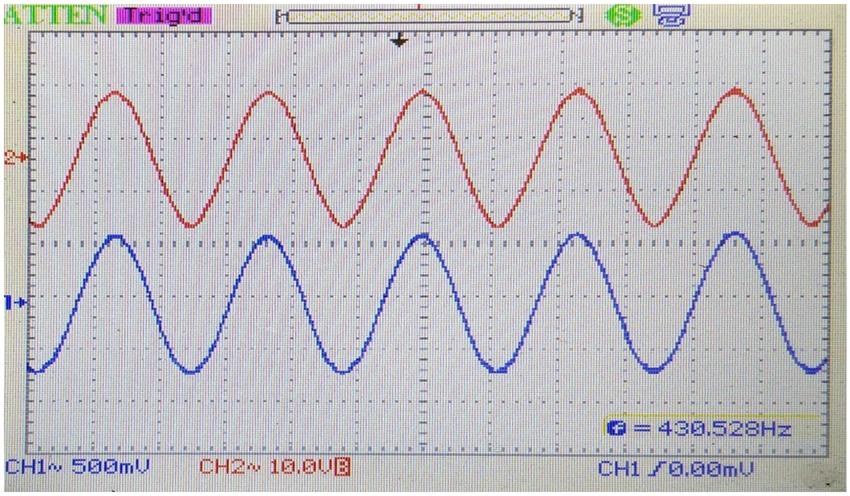

Figure 7 Exciting signal (blue) and resonant signal (red) observed on oscilloscope

6) After taking all data at these sets of points, draw the curve and determine the resonant frequency of free ends sample using extrapolation method.

7) Exchange test samples and repeat Steps 3~6.

8) Use Eq. (22) and Table 1 to calculate material's Young's modulus of these samples.

Note: We introduce 4 methods for finding and determining resonant peak as follows:

1) Estimate the resonant location using theoretical formula, and search resonant point around the theoretical location.
2) Method of recognizing resonant peak: amplitude varies sharply with change in frequency around a real resonant point, while amplitude variation is much smooth around fake resonant points.
3) Method of coupling decline: when the exciting amplitude is sharply reduced, the decay of a real resonant peak is slow, while the decay of fake resonant peaks disappears immediately.
4) Method of coupling withdraw: when the test sample is lift suddenly, a real resonant peak disappears immediately, while a fake resonant peak changes little and decays slower.

Tables for recording experimental data

1) Measured diameter of test sample

Sample \ No.	1	2	3	4	5	6	Average
Brass rod							
Steel rod							
Aluminum rod							

2) Measured resonant frequency at different points of receiver and exciter

Sample \ Frequency *f* (Hz) \ Position *x* (cm)	1.0	2.0	3.0	4.0	5.0	6.0	7.0	Extrapolation
Brass								
Steel								
Aluminum								

3) Calculated results

Material	Mass (g)	Length (mm)	Dia. (mm)	Resonant Freq. (Hz)	Young's Modulus (10^{10}N/ m^2)		Error
					Experimental	Theoretical	
Brass							
Steel							
Al							

3. Examples of Data Recording and Processing

Note: Following data are for reference purpose only, not the criteria for apparatus performance:

1) Measured diameter of test sample

Sample \ No.	1	2	3	4	5	6	Average
Brass rod	6.00	6.02	6.02	6.00	5.98	5.98	6.00
Steel rod	5.98	5.98	5.98	6.00	6.00	6.00	5.99
Aluminum rod	6.02	6.02	6.00	6.00	6.00	6.02	6.01

2) Measured resonant frequency at different points of receiver and exciter

Frequency *f* (Hz) \ Position *x* (cm)	1.0	2.0	3.0	4.0	5.0	6.0	7.0	Extrapolation

Sample									
Brass	Suspending	462.2	454.2	449.5	447.0	447.3	448.9	451.8	446.9
	Supporting	434.6	441.1	444.8	447.4	447.0	445.9	443.9	447.4
Steel	Suspending	696.2	691.5	688.6	687.3	687.5	688.1	689.4	687.3
	Supporting	657.1	672.3	681.2	686.5	686.5	683.0	678.2	687.0
Al	Suspending	695.8	687.0	683.6	681.6	—	690.8	692.3	681.9
	Supporting	604.6	641.6	671.5	682.4	682.0	673.0	660.5	683.6

3) Extrapolation method

Plot these experimental data of the corresponding method of each sample, as shown in Figures 7, 8 and 9 below. Draw a vertical line at the theoretical nodal point (0.224l) (here, sample length is 20 cm, so nodal point is at 4.48 cm). The frequency value at the intersection point of the curve is the resonant frequency achieved by the extrapolation method. If possible, using a mathematical software tool to do curve fitting, so higher accuracy of resonant frequency can be achieved.

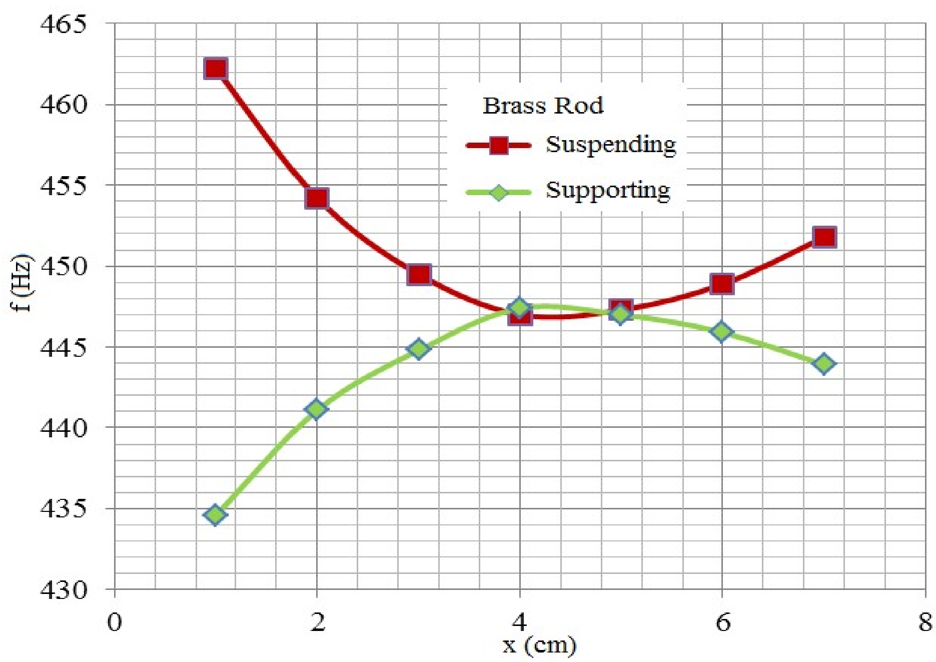

Figure 7 Experimental curve of resonant frequency – brass rod

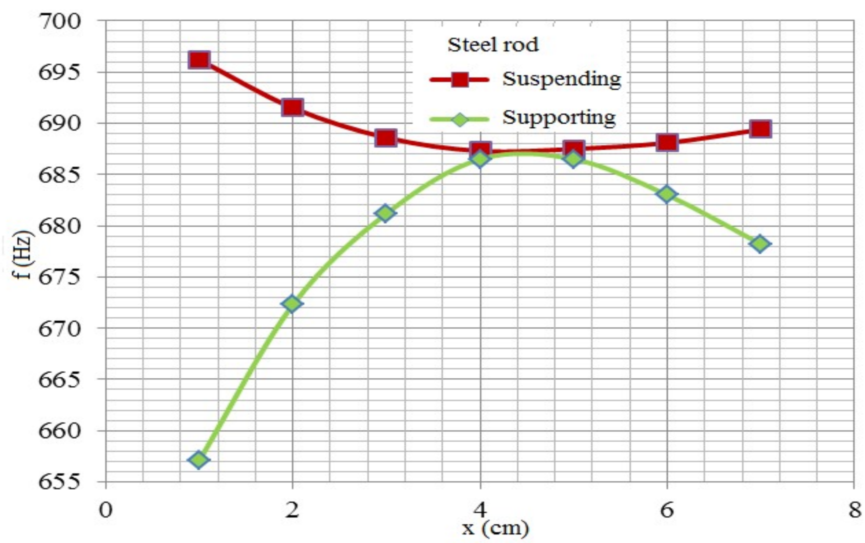

Figure 8 Experimental curve of resonant frequency – steel rod

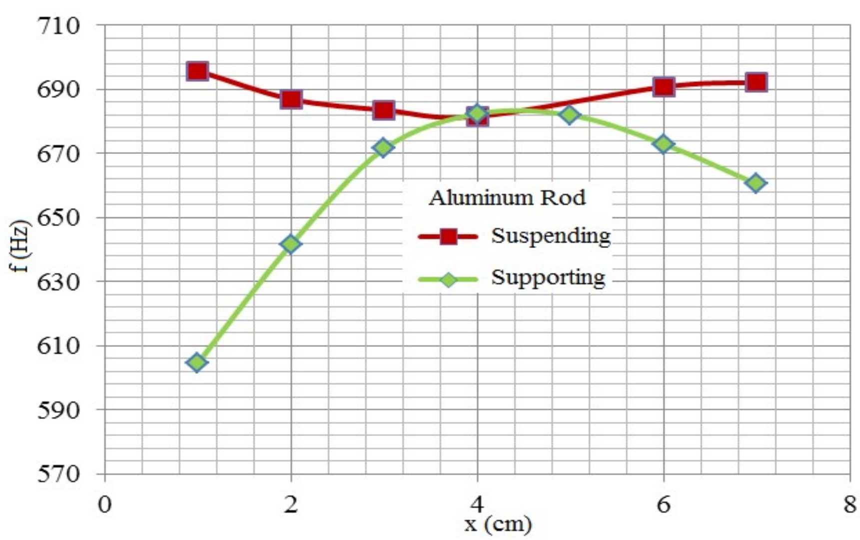

Figure 9 Experimental curve of resonant frequency – aluminum rod

4) Calculated results

Material	Mass (g)	Length (mm)	Dia. (mm)	Resonant Freq. (Hz)	Young's Modulus ($10^{10}N/m^2$)		Error
					Experimental	Theoretical	
Brass	48.6	200	6.00	447.4	9.70	9.69	0.1%
Steel	44.5	200	5.99	687.0	21.07	20.60	2.28%
Al	15.3	200	6.01	683.6	7.08	7.00	1.14%