F15 Mechanical Wave and Resonance

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2 Introduction

2.1 Analyze resonant property and frequency of standing wave

When a string with uniform mass, one side of it is fixed, while the other oscillates up and down regularly, there are waves propagating along it continuously. If particles on the string are vertical to the propagating direction, it is called transverse wave. The highest point of the wave is called peak, and the lowest point is called trough. Distance between each peak or trough is called wavelength λ. If oscillating frequency is f, velocity of wave is V,

$$V=f\lambda \cdots\cdots\cdots(1)$$

Besides, velocity V, tension Y and mass per length M have the relation:

$$V=\sqrt{\frac{Y}{M}}\ldots\ldots\ldots\ldots(2)$$

$$\therefore \quad f\lambda=\sqrt{\frac{Y}{M}}\ldots\ldots\ldots\ldots(3)$$

$$f=\frac{1}{\lambda}\sqrt{\frac{Y}{M}}\ldots\ldots\ldots\ldots(4)$$

If the length of string and tension are controlled properly, two waves with same amplitude and different direction will form standing wave. Let n be the number of standing wave, namely, half the wavelength, and l be the length, then wavelength $\lambda=2\ell/n$. Substitute this into equation (4), we can get frequency f is :

$$f=\frac{n}{2\ell}\sqrt{\frac{Y}{M}} \qquad (5)$$

2.2 Chladni Plates

Observing two-dimension standing wave oscillation and graphics of resonance of plates with different shapes is the famous Chladni Plates. The phenomenon and simple procedure of this experiment are often used to illustrate the working principles of drums or violin and so on, which is application to the design and measurement of resonant frequency of these relative musical instruments. Analogous skills can be used to detect density and stress distribution of object's surface and to search defects of object which can not be seen by human eyes. Furthermore, it is also extended to make further understanding of electromagnetic waves propagating in matters, discuss the resonance of electromagnetic waves and understand the effect of boundary conditions of matters for resonance of electromagnetic wave.

2.3 Bohr atom model

In this experiment, we observe standing wave and conditions for resonance of ring. In addition to discussing ring-shaped musical instruments or other phenomenon, principles and applications of resonant system, we can explain simply why the electrons inside an atom have to rotate around the nucleus in a specific orbital radius according to classical mechanics. Furthermore, we can proceed to illustrate the reason why the energy levels of electrons in atoms are discrete, understanding deeply Bohr atom model in quantum mechanics.

2.4 Standing wave of spring

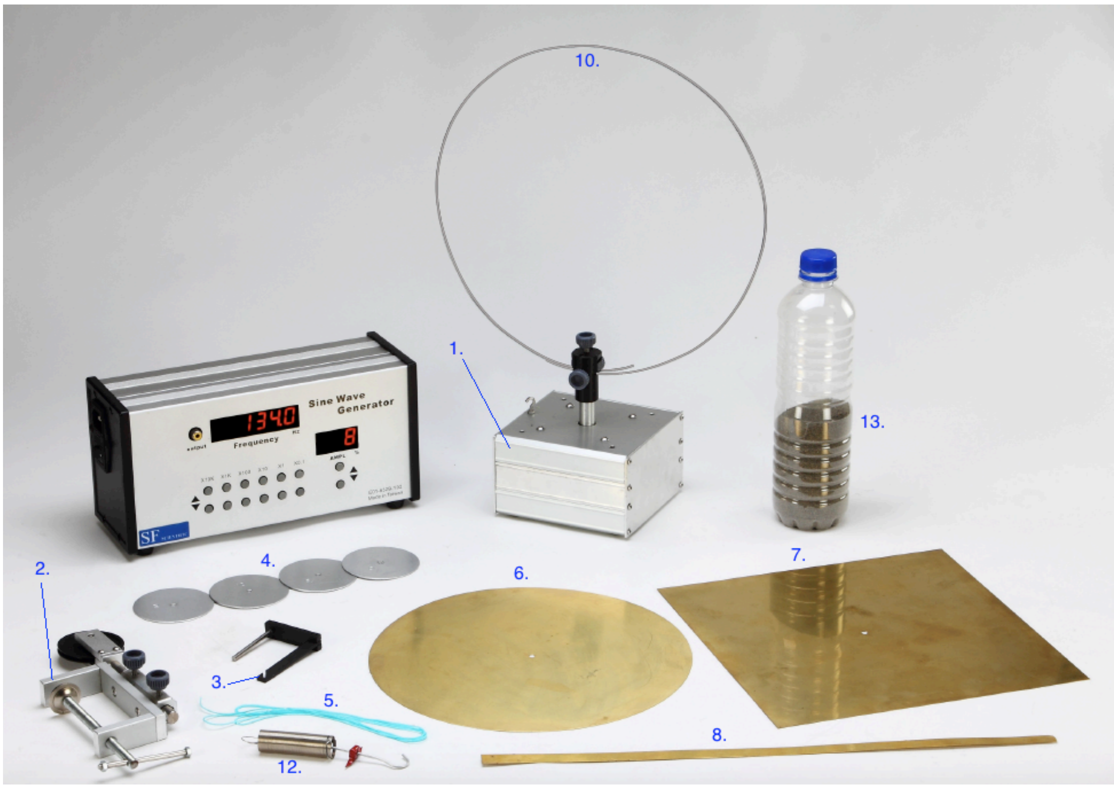
Observing the oscillation of longitudinal wave and resonant phenomenon of spring and discussing the main determinants of resonant frequency, we can understand the wave phenomenon, resonance of acoustic wave and voice mechanism of pipe instruments.

2.5 Resonance of metal strip

Observing the oscillation of transverse wave of metal strip, we can illustrate the standing wave phenomenon of strip-shaped materials and discuss the relation between length of strip and resonant frequency. This experiment can confirm the relation between length of thin cantilever and resonant frequency and wavelength, which is the working principle of strip-shaped sounding bodies such as piano, xylophone, ㄒ

vibraphone and so on. Moreover, the oscillating phenomenon in micro-scale that can't be observed by human eyes and microscope can be realized through this experiment.

3 Equipment



3.1 Vibrator x1

3.2 Precision pulley with table clamp x1

3.3 U-type aluminum hanger x1

3.4 Aluminum weight 10g x4

3.5 String with different mass x3

3.6 Circular metal plate Φ25cm x1

3.7 Square metal plate 25x25cm x1

3.8 Metal stripe 40x1cm x1

3.9 Metal rod 60cm x1

3.10 Circular metal or plastic wire x1

3.11 Spring hanger x1

3.12 Spring x1

3.13 Sands

3.14 Options

3.14.1 Sine wave signal generator x1

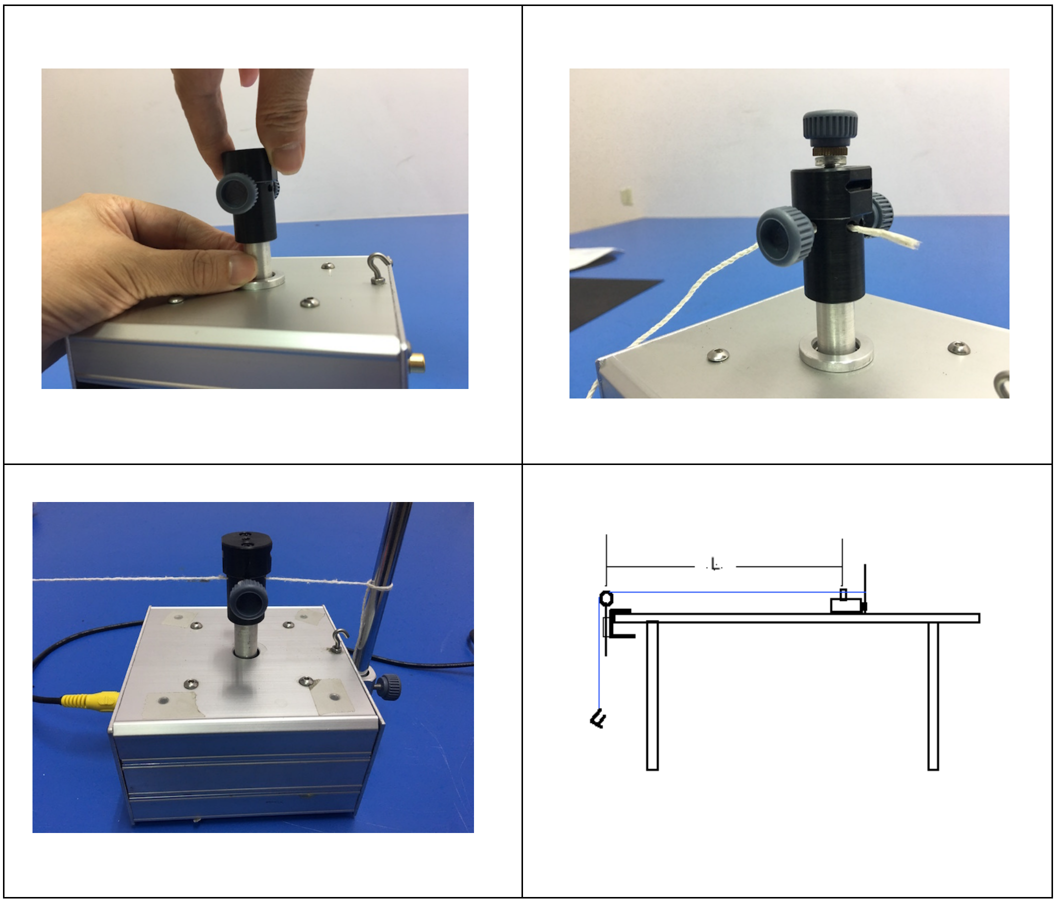
3.14.2 Violin plate x1

4 Installation, Procedure and Result

4.1 Analyze resonant property and frequency of standing wave

4.1.1 Installation

4.1.1.1 Assemble the equipment up. See figure



Note:

1. The vibrator is made by a alum. pole with gum in the center of a loudspeaker. Please use one hand to fix the pole and another hand rotate the plastic fixer into the pole.
2. The Sine wave signal generator operation when you keep on push the button the frequency digital will also continue changing until you release your finger.
3. The function of "Ampl.", we suggest use range 5%~40% when working with this louder speaker.

4.1.2 Procedure

4.1.2.1 After the installation, fix the pulley on one side and hang weights on it.

4.1.2.2 Set the frequency desired to observe and open vibrator.

4.1.2.3 Adjust length or mass of weight until it produces obvious standing wave.

4.1.2.4 Observe the number of standing wave and measure the mass of weights and the length. Substitute them in the below equation and calculate the oscillating frequency.

$$f = \frac{n}{2\ell}\sqrt{\frac{Y}{M}}$$

4.1.2.5 After getting theoretical value from procedure 4.1.2.4, compare it with the frequency set in 4.1.2.2.

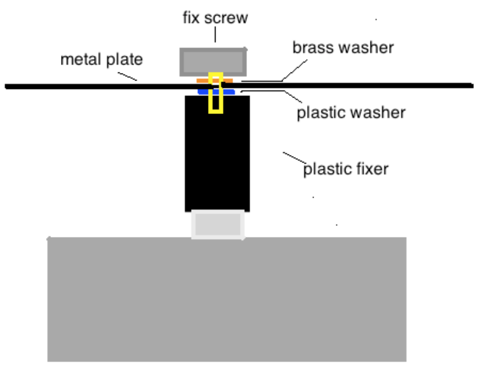
4.1.2.6 Result sample

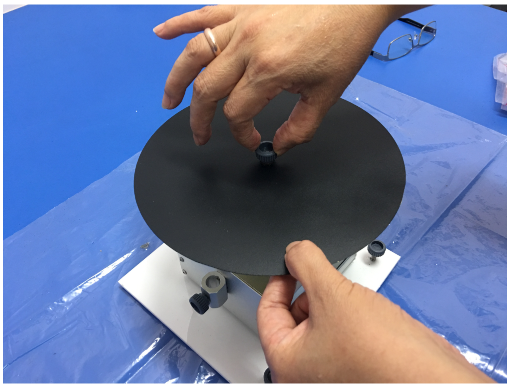
total string length (m)	Total string mass (kg)	mass per length (M) (kg/m)	weight mass (kg)	Tension from vertical string + weight (Y/N)	effective string length (l/m)	number of standing wave (n)	theoretical frequency (Hz)	experiment frequency (Hz)	error rate (%)
2.80	0.00092	0.000329	0.02134	0.20913	0.8	5	78.8	82.2	-4.09%
2.80	0.00092	0.000329	0.02128	0.20854	1.0	5	63.0	66.0	-4.57%
2.80	0.00092	0.000329	0.02121	0.20786	1.2	3	31.4	32.7	-3.85%
2.80	0.00092	0.000329	0.02121	0.20786	1.2	4	41.9	43.7	-4.07%
2.80	0.00092	0.000329	0.02121	0.20786	1.2	5	52.4	54.6	-4.03%
2.80	0.00092	0.000329	0.03136	0.30733	1.2	5	63.7	66.4	-4.04%
2.80	0.00092	0.000329	0.04150	0.40670	1.2	5	73.3	76.6	-4.31%

4.2 Chladni Plates

4.2.1 Installation

4.2.1.1 Assemble the equipment up. See figure





Note:

The vibrator is made by a alum. pole with gum in the center of a loudspeaker. Please use one hand to fix the plate and another hand rotate the plastic screw into the pole.

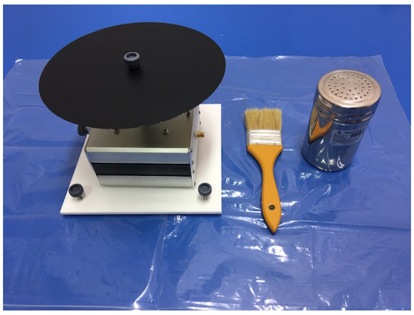
4.2.2 Procedure

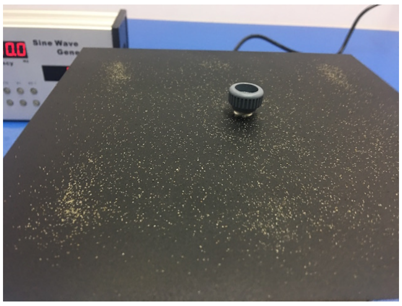
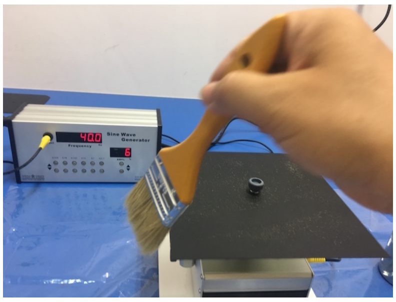
4.2.2.1 After the installation, spread thin sand on the plate.

4.2.2.2 Patient to set the frequency and ampl desired to observe and open vibrator.

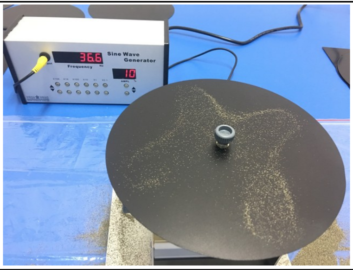
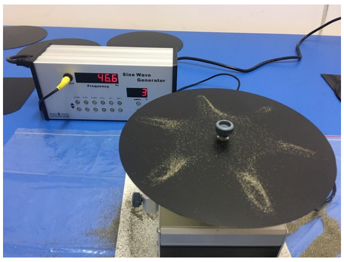
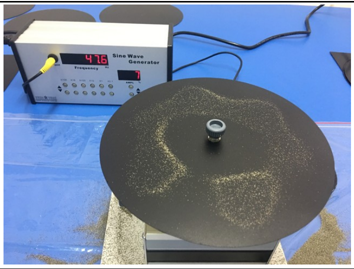
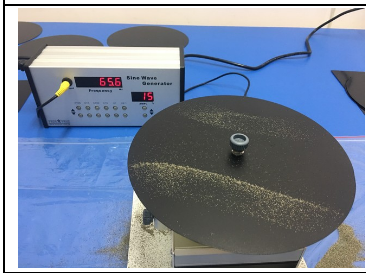
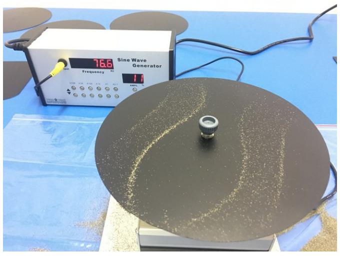
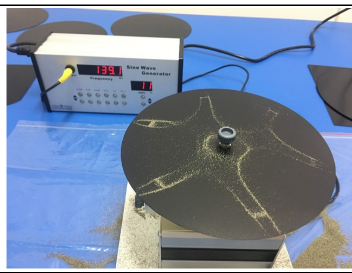
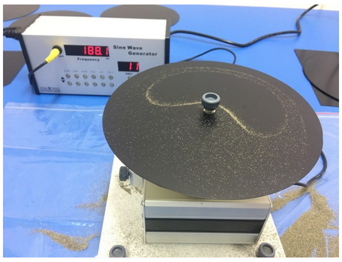
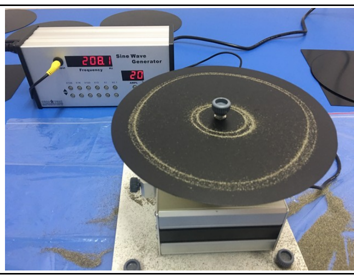
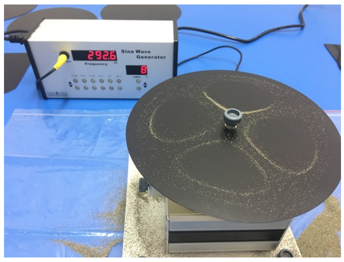
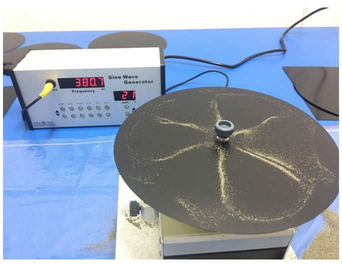
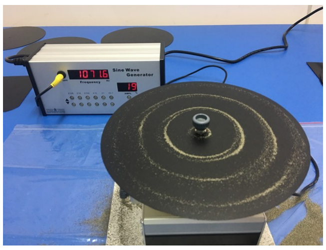
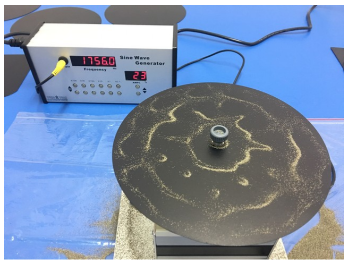
4.2.2.3 If you spread a lot of sand on the plate and it seems not so uniform to make a good picture please clean it by a brush and spread sand again under the resonant frequency.

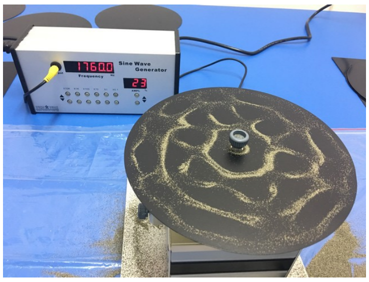
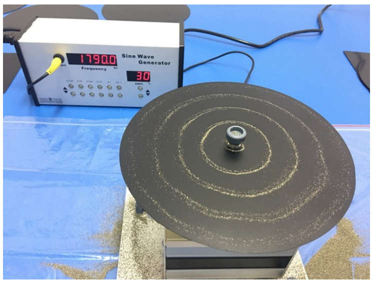
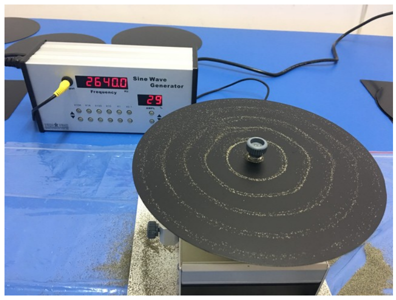
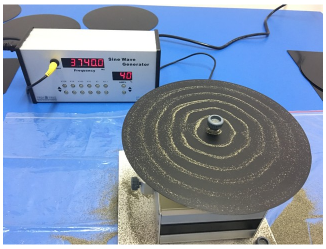
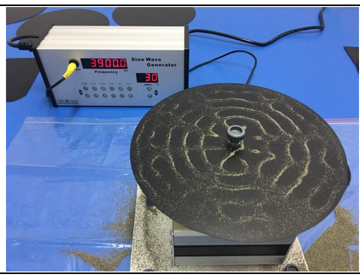
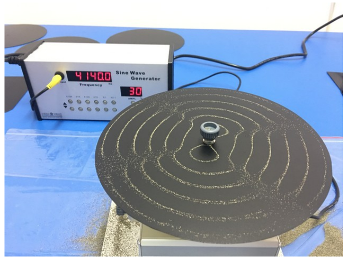
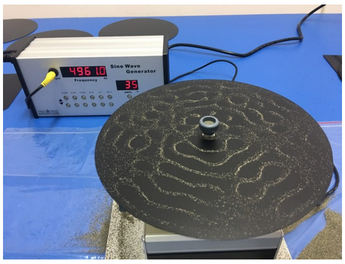
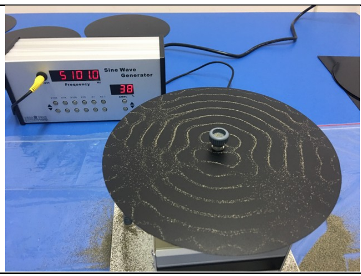
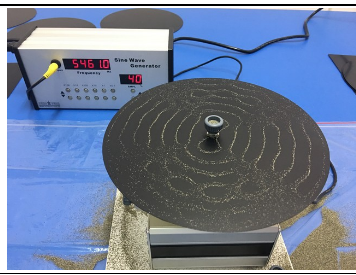
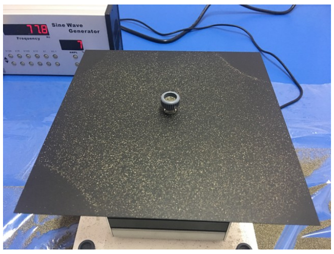
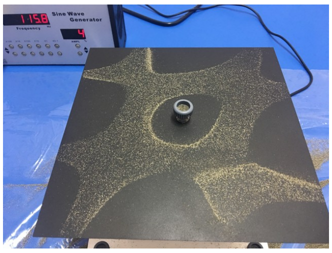
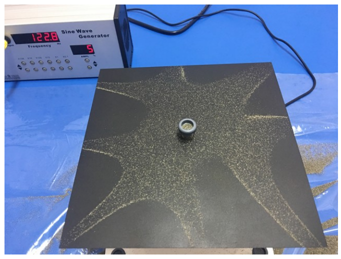
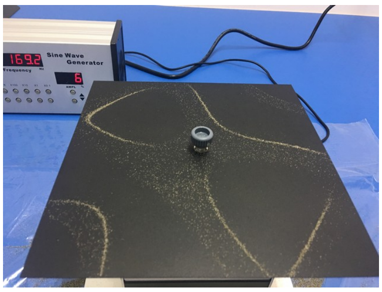
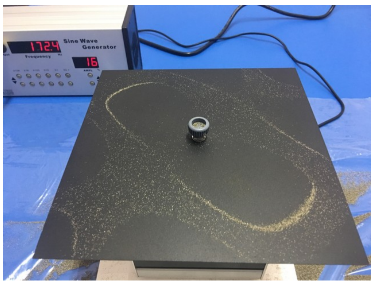
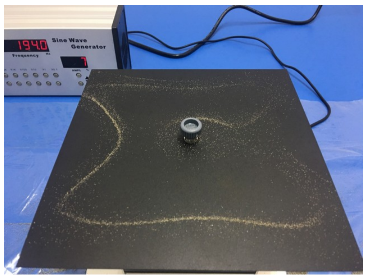
4.2.2.4 Plate made by different material size thickness will have different answer.

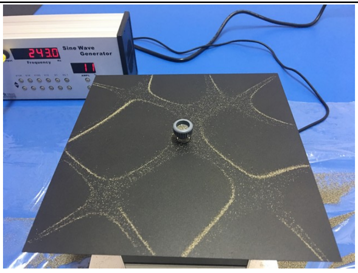
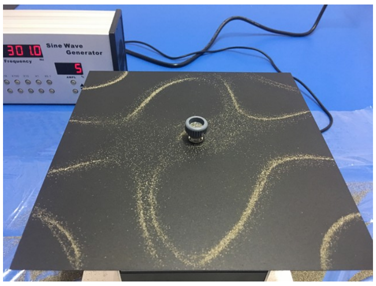
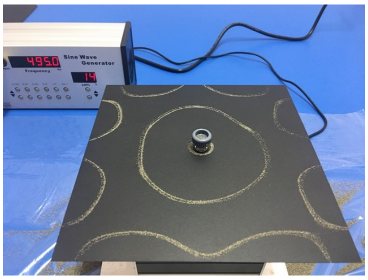
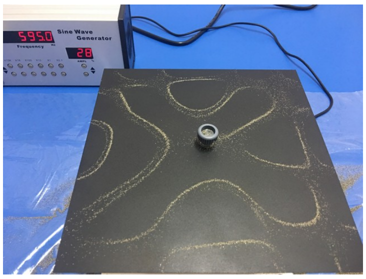
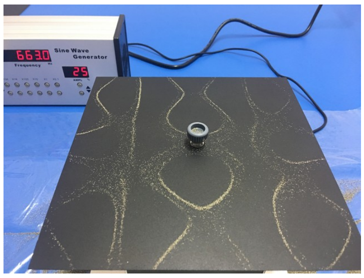
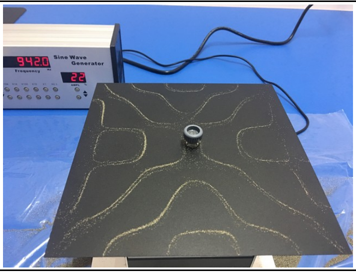
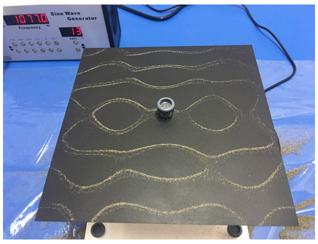
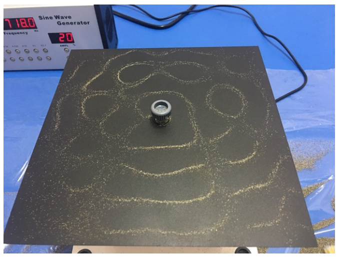
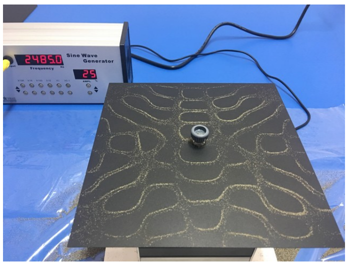
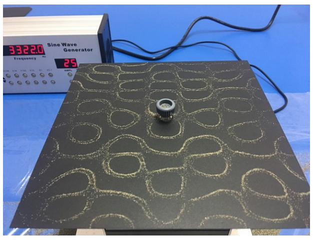
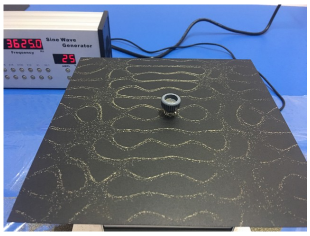
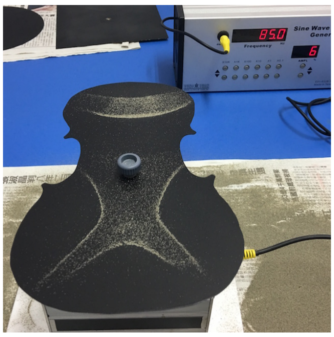
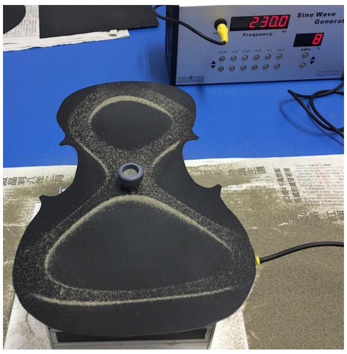


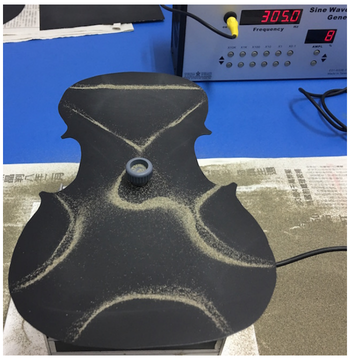
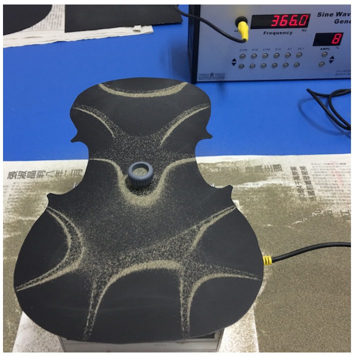
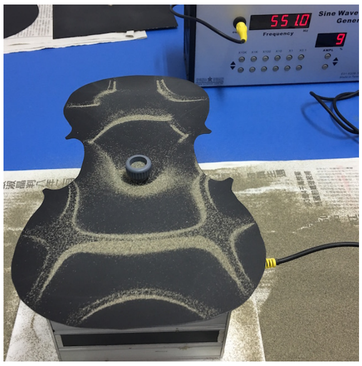
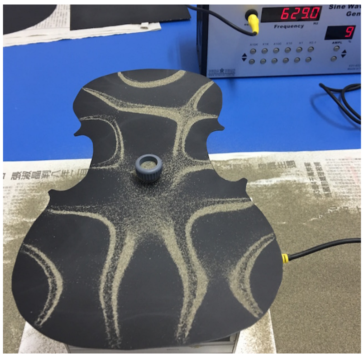
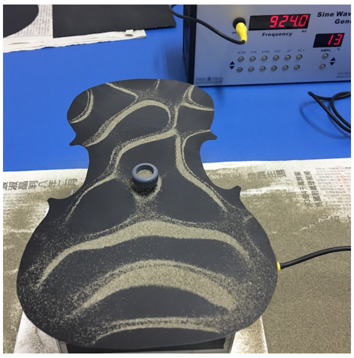
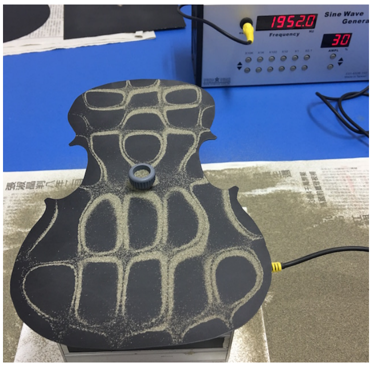
	

4.2.2.4. Sample result:

Brass /Round plate /Thickness 0.5mm/Diameter Φ200mm		
		
36Hz	46Hz	47Hz
		
65Hz	76Hz	139Hz
		
188Hz	208Hz	392Hz
		
380Hz	1071Hz	1756Hz

		
1760Hz	1790Hz	2640Hz
		
3740Hz	3900Hz	4140Hz
		
4961Hz	5101Hz	5461Hz
Brass /Square plate /Thickness 0.5mm/200mmx200mm		
		
77Hz	115Hz	122Hz
		
169Hz	172Hz	194Hz

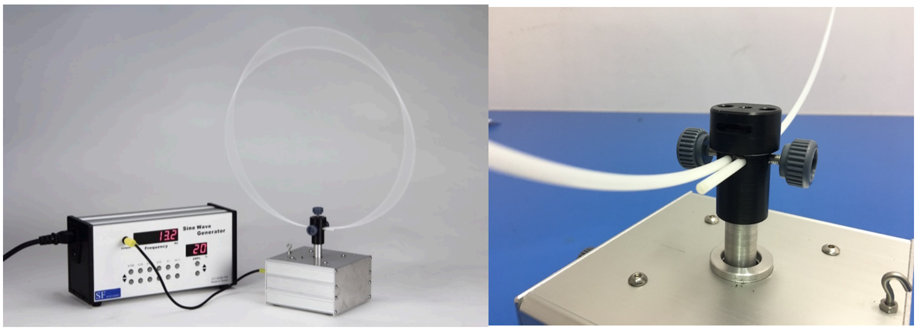
		
243Hz	301Hz	495Hz
		
595Hz	609Hz	633Hz
		
942Hz	1077Hz	1718Hz
		
2415Hz	3322Hz	3625Hz
Brass /Violin plate /Thickness 0.4mm (Option parts)		
		

85Hz	180Hz	230Hz
		
305Hz	366Hz	551Hz
		
629Hz	924Hz	1952Hz

4.3 Bohr atom model

4.3.1 Installation

4.3.1.1 Assemble the equipment up. See figure.



4.3.2 Procedure

4.3.2.1 After the installation, set the frequency desired to observe and open vibrator.

4.3.2.2 Observe oscillations under different frequencies with fixed radius.

4.3.2.3 Fix the frequency and observe oscillations of metal strips with different radius.

4.4 Standing wave of spring

4.4.1 Installation

4.4.1.1 Assemble the equipment up. See figure (4).

Fig.(4)

4.4.2 Procedure

4.4.2.1 After the installation, set the frequency desired to observe and open vibrator.

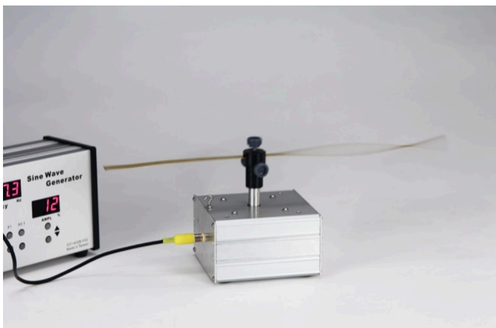
4.4.2.2 Observe oscillations under different frequencies with fixed length.

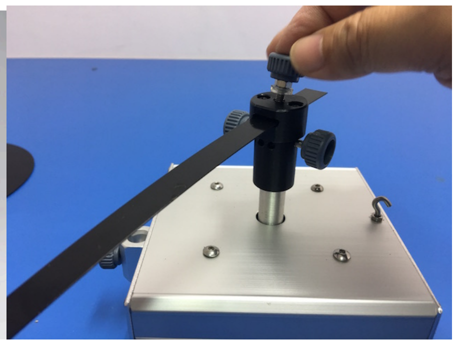
4.4.2.3 Observe oscillations of different metal strips with fixed frequency.

4.5 Resonance of metal strip

4.5.1 Installation

4.5.1.1 Assemble the equipment up. See figure.





4.5.2 Procedure

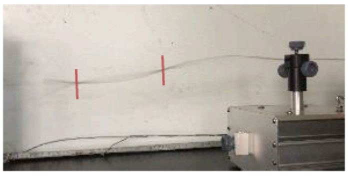
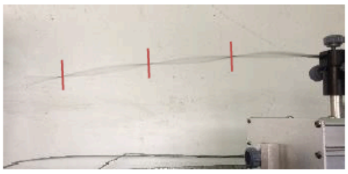
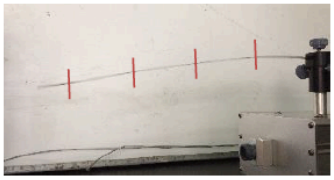
4.5.2.1 After the installation, set the frequency desired to observe and open vibrator.

4.5.2.2 Observe oscillations under different frequencies with fixed length.

4.5.2.3 Observe oscillations of different metal strips with fixed frequency.

4.5.3 Result sample

4.5.3.1 Strip length 27.7cm

f=55.3 Hz	f=108.9 Hz	f=183.8 Hz
		

4.5.3.2 Strip length 36cm

f=31 Hz	f=61 Hz	f=104 Hz