4. Experimental Objectives

1) Study the relationship between amplitude and force frequency of a tuning fork vibration system drove by a periodically external force. Measure and plot their relationship curve, and acquire the resonance frequency and the sharpness of the vibration system (this value is equal to the Q value).
2) Measure the relationship between the vibration and the mass of symmetrical arms of the tuning fork. Acquire the relationship formula between the vibration frequency f (i.e. resonance frequency) and the block mass m attached to the tuning fork arms at a certain position.
3) Measure the mass of a pair of mass blocks attached to the tuning fork arms by measuring the resonance frequency.
4) Measure the resonance frequency and sharpness of the tuning fork when changing the vibration structure and increasing the damping force of the tuning fork and do comparison.

5. Precautions

1) Do not loosen the fixing screws at will to avoid breaking the lead of solenoid coil.
2) The sensor is a sensitive part, which is protected by a protective cover. Do not remove the protective cover or use a tool to extend into the protective cover to avoid damage to the electromagnetic coil sensor and the lead.

6. Experimental Procedures

Must do experiment:

1) Use a shielded signal wire to connect the output port of the signal source to the voltage input port of the excitation coil. Use a shielded signal wire to connect the signal output port of the electromagnetic coil to the input port of the signal receiving amplifier.
2) Turn on the power and warm up for 15 minutes.
3) Measure the resonance frequency f_0 and amplitude A_r.

   Adjust the "Amp. Adj." (i.e. amplitude adjustment) knob to a moderate position. Slowly adjust the output frequency of the low-frequency signal generator from low to high (reference value is about 250 Hz). Carefully observe the change of the effective value of the AC voltage. When the reading reaches the maximum value, record the frequency as resonance frequency f_0 of the tuning fork and the effective value of the voltage. (can use the "Scan" key to automatically scan the resonance frequency).

4) Measure the relationship between the sensor output of the tuning fork vibration system and the drive signal frequency f.

   When the output of the signal generator remains unchanged, change the frequency from low to high, measure the effective value A of the voltage and the frequency f of the driving force. Note that more points should be measured near the resonance frequency.

5) Draw the $A \sim f$ relationship curve. Find the two half power points f_1 and f_2, and calculate the sharpness (Q value) of the tuning fork using the formula $Q = \frac{\omega_0}{\omega_2 - \omega_1} = \frac{f_0}{f_2 - f_1}$.

6) Measure the mass values of different masses on an electronic balance and record the measurement results.

7) Add different masses to the designated positions of the arms of the tuning fork and tighten them with screws. Measure the resonance frequency when the tuning fork arms are symmetrically added with the same mass. Record $m \sim f$ relation data.

8) Make a plot of the relationship between the period square T^2 and the mass m, and find the slope B and the intercept m_0 of the straight line on the m-axis.

9) Replace the known mass block with a pair of unknown masse blocks m_x, measure the resonance frequency f_x of the tuning fork and derive the unknown mass m_x.

Optional experiment:

1) Observe the input signal of the excitation coil and the output signal of the electromagnetic coil sensor with an oscilloscope, and measure their phase relationship.

2) At the same position of both arms of the tuning fork, use small magnetic steels to suck two pieces of stainless steel respectively onto the two arms, and drive the tuning fork with electromagnetic force. Measure the resonance frequency and sharpness (Q value) of the tuning fork when changing the vibration mechanism and increasing air damping.

3) Partially immerse the two damping pieces in liquid (such as water or oil), and observe the changes in resonance frequency and sharpness of the tuning fork. (Note that the amplitude of the vibration cannot be too large, so as not to cause water splashes)

7. An example of data recording and processing

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

1) Relationship between amplitude A_r and frequency f

Slowly adjust the output signal frequency of the low-frequency signal generator from low to high (reference value is about 250 Hz). Carefully observe the reading of the AC digital voltmeter, record the frequency f_i of the tuning fork vibration and the reading of the AC voltmeter A_r, and the recorded data is shown in the Table 1.

Table 1 Data of frequency f and amplitude A_r

f (Hz)	246.00	246.50	247.00	247.50	248.00	248.50	249.00	249.10	249.20
A_r (mV)	78	85	92	103	118	138	172	180	191
f (Hz)	249.30	249.40	249.50	249.60	249.70	249.80	249.90	250.00	250.10
A_r (mV)	202	216	232	249	274	302	341	390	466
f (Hz)	250.15	250.20	250.25	250.30	250.35	250.40	250.50	250.60	250.70

A_r (mV)	527	634	818	998	1166	1122	1034	944	845
f (Hz)	250.80	250.90	251.00	251.10	251.20	251.30	251.40	251.50	252.00
A_r (mV)	755	663	584	508	445	391	343	305	183
f (Hz)	252.50	253.00	253.50						
A_r (mV)	123	89	69						

The plot of data in Table 1 is shown in Figure 3.

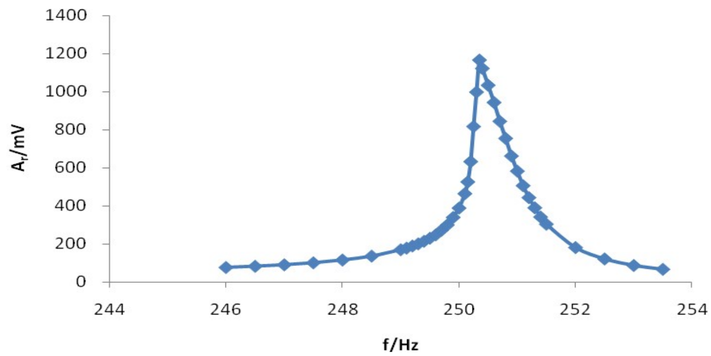

Figure 3 Relationship between amplitude A_r and frequency f

The resonance point is located at the frequency $f_0 = 250.35Hz$. At this time, the effective voltage value is $A_r = 1166mV$, and the half-power voltage is $\frac{1166mV}{\sqrt{2}} = 825mV$. At this time, $f_1 = 250.25Hz$, $f_2 = 250.72Hz$, the quality factor $Q = \frac{f_0}{f_2 - f_1} = 532.66$.

2) Relationship between the resonance frequency of the tuning fork and the mass of both arms

In order to study the relationship between the resonance frequency of the tuning fork and the mass of the two arms, paired metal blocks of known mass are added to the specified symmetrical mark line positions of the tuning fork, and the output signal frequency of the low-frequency signal generator is adjusted to find the resonance frequency. Paired bocks of different masses are added and measured one by one. The masses and the corresponding resonance frequencies of the tuning fork are recorded in Table 2.

Table 2 Resonance frequency and corresponding mass added to both arms

m/g	0	27.71	36.97	47.99	67.43	78.08
f_0/Hz	250.35	240.24	235.89	231.59	224.31	221.14
$T^2 \times 10^{-5}/s^2$	1.596	1.732	1.797	1.864	1.987	2.045

The linearly fit of the data in Table 2 is shown in Figure 4.

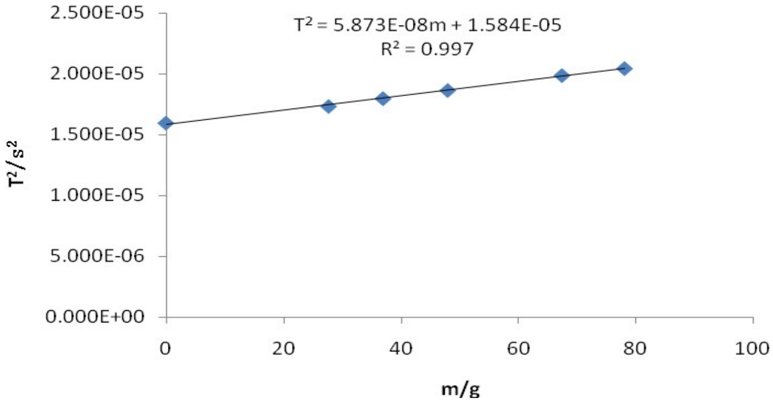

Figure 4 The relationship between the square of the resonance period and the mass of both arms

Mount a pair of masses of unknown mass at the specified symmetrical mark line position. The measured resonance frequency is $f_0 = 227.90Hz$ .At this time, $T^2 = 1.925\times10^{-5}s^2$. Substitute it into the straight line formula obtained by fitting, the mass of the unknown mass is $m_x = 58.12g$. Measure it with an electronic balance, it is $m = 58.91g$. The error is less than 2%.