2.1.1: Simple Harmonic Motion

An object will not vibrate if there is no restoring force causing it to want to return to its equilibrium position. If this force is proportional to the distance from equilibrium it is a ***linear restoring force*** and obeys ***Hooke's law***. Hooke's law says that if we double the displacement from equilibrium, the force acting to return the object to the equilibrium position also doubles. If the displacement is one third as big the force is one third as big and so on. Most springs obey Hooke's law; the more you stretch the spring, the larger the force.

What if the force is not proportional to the displacement? Such a force is called a ***non-linear force*** which does not obey Hooke's law. An example is the modern compound bow used in archery. A system of pulleys causes the force to be the smallest when the displacement is greatest. This makes it easier for the archer to hold the bow at maximum displacement while he or she aims at the target. Non-linear forces can be quite complicated but fortunately most forces involved in sound and musical instruments are close enough to linear that we can ignore non-linear effects. The few times a non-linear force acts will be explicitly mentioned; in all other cases you can assume the forces are linear.

The simplest of all vibrations occurs when there is a Hooke's law force and no friction acts. This type of motion is called ***simple harmonic motion*** and will be the model we will use for vibrations in musical instruments. A free hanging mass on a spring and a pendulum swinging with low amplitude approximately obey simple harmonic motion.

If friction acts the motion will gradually stop. This is called ***damped harmonic motion***. To maintain a constant vibration when there is friction, a periodic force must be applied. Harmonic motion that has damping and an applied periodic force is called ***damped, driven harmonic motion*** and will be discussed further in the next chapter.

Questions on Simple Harmonic Motion:

1. How is sound created?
2. How would you determine the period of a pendulum?
3. How are frequency and period related?
4. Define the units of frequency.
5. What is the difference between ‘amplitude’ and ‘displacement’? In the strict sense, why aren’t these terms interchangeable?
6. If the period of an oscillation doubles, what happens to the frequency?
7. The frequency of middle C sound wave is 262 Hz. What period of oscillation which produces this sound?
8. What is the period of oscillation of a string if the frequency is 200 Hz?
9. What is the frequency of oscillation if the period is 1.2 s?
10. A cork fishing float bobs up and down 15 times per minute. What is period of oscillation in seconds? What is the frequency in Hertz?
11. What is the period of the second hand of a watch for going all the way around once?
12. The frequency of a local radio station is 89.3 MHz (M = mega = 106). What is the period of oscillation of the electromagnetic waves of this signal?
13. If the CPU of a computer from the year 2000 is 200 MHz, what would the period of oscillation be?
14. If you hang a larger mass on the same spring, what happens to its period?
15. The average guitar has six strings each in ascending thickness. How might the thickness affect the frequency of the sound from each string when plucked?
16. Suppose a vibrating guitar string moves a total distance of 1.0 cm from it’s maximum in one direction to the maximum in the other direction. What is the maximum amplitude for this motion?
17. Suppose a clarinet reed vibrates with a maximum amplitude of 0.04 cm. How far does it travel in a complete cycle (all the way back to its starting point)?
18. What does the phase of an oscillation tell you about its motion?
19. A phase of 270 degrees is how many radians?
20. A phase of 200 degrees is how many radians?
21. Define simple harmonic motion.
22. What conditions are required for simple harmonic motion to occur?
23. What is Hooke’s law and why is it important?
24. What is the difference between a linear force and a non-linear force?
25. Which has the larger period, a stiff spring or a soft spring?

26. Which has the larger frequency, a stiff spring or a soft spring?
27. Which has the larger period, a small mass hanging from a spring or a large mass hanging from the same spring?
28. What kind of clarinet reed would more easily play low frequency notes, a stiff reed or a soft reed (assuming the mass is the same)? Explain your thinking.
29. What kind of saxophone reed would more easily play low frequency notes, a thick, heavy reed or a thin, light reed (assuming the stiffness is the same)? Explain your thinking.
30. The mathematical description of SHM is given by $y(t) = A\cos(2\pi ft + \phi)$. Explain what each of the terms $(A, \cos, \pi, f, t, \phi)$ represent in the motion of a mass on a spring.