Chapter 4

Terms

Be able to define or discuss the following terms and ideas, with their SI units if appropriate.

1. contact force
2. spring-ball model of a solid
3. tension
4. length of an interatomic bond
5. bond stiffness
6. springs in series
7. springs in parallel
8. cross-sectional area
9. stress
10. strain
11. Young's modulus
12. yield stress
13. static equilibrium (i.e. equilibrium)
14. harmonic oscillator
15. angular frequency
16. period
17. amplitude
18. phase
19. analytical solution for a harmonic oscillator
20. transverse wave
21. longitudinal wave
22. wave speed
23. wavelength
24. wavenumber
25. frequency (of a wave)
26. transverse standing wave on a string that is fixed at both ends
27. node
28. antinode
29. longitudinal standing wave in a pipe that is open on one end
30. longitudinal standing wave in a pipe that is open on both ends
31. pressure nodes and antinodes for a longitudinal standing wave

Equations

Understand the meaning and know the SI units of all symbols in these equations; know how to perform each mathematical operation, such as trig functions; know how to solve for any unknown quantity; understand how changing one quantity affects another quantity (if all other quantities remain constant); be able to apply one or more equations to solve a problem.

- For springs in series:
$$\frac{1}{k_{eff}} = \frac{1}{k_1} + \frac{1}{k_2} \tag{1}$$
- For springs in parallel:
$$k_{eff} = k_1 + k_2 \tag{2}$$
- $$strain = \frac{\Delta L}{L} \tag{3}$$
- $$stress = \frac{F_T}{A} \tag{4}$$
- Young's Modulus:
$$Y = \frac{stress}{strain} \tag{5}$$
- $$k_{bond} = Y d_{atom} \tag{6}$$
- $$x = A\cos(\omega t + \phi) \tag{7}$$
- $$T = \frac{2\pi}{\omega} \tag{8}$$
- $$f = \frac{1}{T} \tag{9}$$
- $$\omega = 2\pi f \tag{10}$$
- Wavespeed:
$$v = \lambda f \tag{11}$$
- For a mass on a spring:
$$\omega = \sqrt{\frac{k}{m}} \tag{12}$$
- For a wave on a string:
$$v = \sqrt{\frac{T}{\mu}} \tag{13}$$
- For a transverse standing wave on a string:
$$\lambda = \frac{2L}{n} \tag{14}$$
- For a transverse standing wave on a string:
$$y = 2A\sin(kx)\cos(\omega t) \qquad k \text{ is the wavenumber, } k = \tfrac{2\pi}{\lambda} \tag{15}$$

- For a pipe that is open on one end:

$$\lambda = \frac{4L}{n} \qquad \text{for n=1, 3, 5 ...} \tag{16}$$

- For a pipe that is open on both ends:

$$\lambda = \frac{2L}{n} \tag{17}$$

Skills

1. Calculate the effective spring stiffness for springs in series.
2. Calculate the effective spring stiffness for springs in parallel.
3. Draw a force vector for tension.
4. Identify and sketch all forces acting on a particle in any given situation.
5. Derive an equation for interatomic bond stiffness of atoms in terms of Young's modulus for the solid.
6. Calculate the diameter of an atom for a given solid.
7. Calculate the stiffness of a bond if given how much a metal stretches for a certain tension.
8. Solve for an unknown force on a particle in static equilibrium.
9. Describe what is meant by a person feeling "weightless".
10. Measure or calculate amplitude, period, frequency and angular frequency for a harmonic oscillator if given a graph of x(t).
11. From x(t), calculate $v_x(t)$, and $F_{net,x}(t)$ for a harmonic oscillator.
12. Determine wavelength and amplitude from a picture of a transverse wave.
13. Determine amplitude and period from a graph of y vs. t for a transverse wave or a graph of Δx vs. t for a longitudinal wave.
14. Sketch y vs x for a standing transverse wave on a string for a given harmonic.
15. Sketch Δx vs x for a standing longitudinal wave in a pipe for a given harmonic and for a given pipe.
16. Calculate wavelength and frequency for a given harmonic for a standing wave.

Lab Skills

1. Write a computer program that iteratively calculates net force, velocity, and position of a harmonic oscillator.
2. Measure the effective spring stiffness of two springs in series; measure the effective spring stiffness of two springs in parallel.
3. Measure Young's modulus and determine the interatomic bond stiffness of a solid.
4. Determine the stiffness of a spring using Hooke's law.
5. Measure the harmonic and wavelength for a standing wave.
6. Determine the linear density of a string from a graph of wavespeed vs. tension.