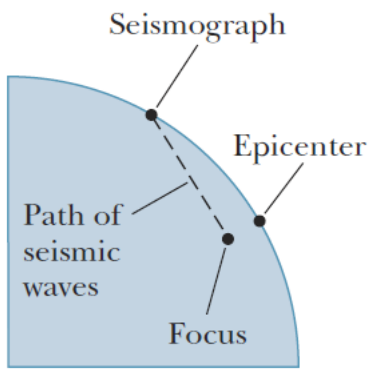
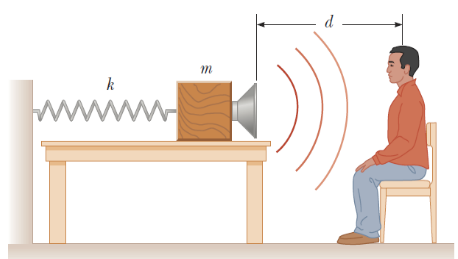
Questions for Module # 19

Q.1 In an earthquake, both S (transverse) and P (longitudinal) waves propagate from the focus of the earthquake. The focus is in the ground radially below the epicenter on the surface. Assume the waves move in straight lines through uniform material. The S waves travel through the Earth more slowly than the P waves (at about 5 km/s versus 8 km/s). By detecting the time of arrival of the waves at a seismograph, (a) how can one determine the distance to the focus of the earthquake? (b) How many detection stations are necessary to locate the focus unambiguously? Solution



Q.2 *The Tunguska event.* On June 30, 1908, a meteor burned up and exploded in the atmosphere above the Tunguska River valley in Siberia. It knocked down trees over thousands of square kilometers and started a forest fire, but produced no crater and apparently caused no human casualties. A witness sitting on his doorstep outside the zone of falling trees recalled events in the following sequence. He saw a moving light in the sky, brighter than the Sun and descending at a low angle to the horizon. He felt his face become warm. He felt the ground shake. An invisible agent picked him up and immediately dropped him about a meter from where he had been seated. He heard a very loud protracted rumbling. Suggest an explanation for these observations and for the order in which they happened Solution

Q.3 A block with a speaker bolted to it is connected to a spring having spring constant *k* and oscillates as shown. The total mass of the block and speaker is *m*, and the amplitude of this unit's motion is *A*. The speaker emits sound waves of frequency *f*. Determine (a) the highest and (b) the lowest frequencies heard by the person to the right of the speaker. (c) If the maximum sound level heard by the person is β when the speaker is at its closest distance *d* from him, what is the minimum sound level heard by the observer?



Answers: (a) $\dfrac{vf}{v - A\sqrt{\dfrac{k}{m}}}$; (b) $\dfrac{vf}{v + A\sqrt{\dfrac{k}{m}}}$; (c) $\beta - (20\text{ dB})\log\left(1 + \dfrac{2A}{d}\right)$

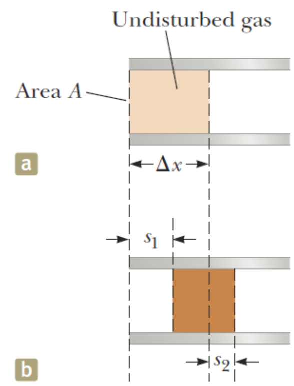
Q.4 In this question you will derive the wave equation for one-dimensional propagation step by step. Proceed as follows:
(a) Draw a force diagram for this element showing the forces exerted on the left and right surfaces due to the pressure of the gas on either side of the element.
(b) By applying Newton's second law to the element, show that,

$$-\frac{\partial(\Delta P)}{\partial x} A\,\Delta x = \rho A\,\Delta x \frac{\partial^2 s}{\partial t^2}$$

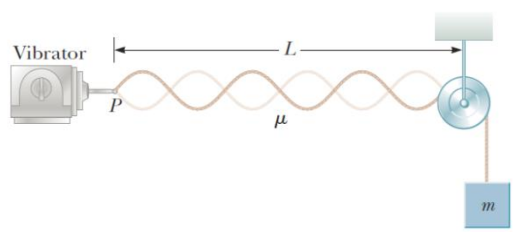
(c) By substituting $\Delta P = -(B\,\partial s/\partial x)$ derive the equation for sound propagation,

$$\frac{B}{\rho}\frac{\partial^2 s}{\partial x^2} = \frac{\partial^2 s}{\partial t^2} \qquad v = \sqrt{B/\rho}.$$

d) Find solutions of the above in the for of exponentials.



Q.5 In the arrangement shown, an object can be hung from a string (with linear mass density m=0.002 kg/m) that passes over a light pulley. The string is connected to a vibrator (of constant frequency *f*), and the length of the string between point *P* and the pulley is *L*=2.00 m. When the mass *m* of the object is either 16.0 kg or 25.0 kg, standin waves are observed; no standing waves are observed with any mass between these values, however. (a) What is the frequency of the vibrator? *Note:* The greater the tension in the string, the smaller the number of nodes in the standing wave. (b) What is the largest object mass for which standing waves could be observed?



Solution

Q.6 By whatever means you are familiar with, show that the function,

$$y(t) = \begin{cases} A & 0 < t < \frac{T}{2} \\ -A & \frac{T}{2} < t < T \end{cases}$$

can be expressed as the Fourier series,

$$y(t) = \sum_n \frac{4A}{n\pi} \sin n\omega t$$