

Section A

1. a (in a longitudinal wave, the material oscillates along the same direction that the wave moves)
2. c (at a particular location, the phase difference between two waves are constantly changing, leading to constructive then destructive then constructive and so on)
3. a (compare Figures 12.3 and 12.5; consider what the “onions” look like)
4. a (assuming the speed of the wave is the same, the longer wavelength corresponds to a lower frequency via $v = \lambda f$)
5. b (since the frequencies are different, the phase difference between the two are constantly changing)
6. d (the eye is only sensitive to a small range of frequencies within the electromagnetic radiation spectrum)
7. a (the difference in length is an integer-multiple of the wavelength)
8. c (sunlight consists of a band of wavelengths, and each wavelength produces a “dot” in a different place)
9. c (the diverging lens diverges the rays, leading to an image on the same side of the lens as the object yet closer to the lens than the object)
10. a (when the object is closer than the focal length, the image is virtual, farther away and larger; when the object is at the focal length, the image is infinitely far away)
11. d (the ratio of object height to object distance is the same as the ratio of image height to image distance)
12. e (diverging lenses create virtual images on the same side of the lens as the object but closer than the object; consequently, the image is upright and smaller than the object)

Section B

1. In this case, we have both a moving source and a moving observer. You can do this in one step but it may be easier to break this down into two steps.

First consider what a stationary observer hears. We'll need to place the stationary observer between the two trains, so the first train is moving toward it, so that the observer intercepts the wave that is traveling from the first train to the second train. The equation for determining the observed frequency is

$$f_{\text{obs}} = f_{\text{source}} \frac{v_{\text{wave}}}{(v_{\text{wave}} \pm v_{\text{source}})}$$

We expect the observer to hear a higher frequency than f_{source} since the source is moving toward it, which leads to the wavefronts “bunching” up on that side. This “bunching” means the wavelength is shorter and a shorter wavelength (for the same wave speed) means the observed frequency is higher.

To get this result, we subtract the source speed (20 m/s) from the wave speed (which we'll assume is 340 m/s in this case). That leads to a lower number in the denominator, which makes the fraction larger. Plugging in, I get an observed frequency of 369.75 Hz.

This problem wants to know what the second train hears. So, let's suppose this stationary observer emits the sound they observe (369.75 Hz). The second train is moving away from the stationary observer. The equation for determining the observed frequency is

$$f_{\text{obs}} = f_{\text{source}} \frac{(v_{\text{wave}} \pm v_{\text{source}})}{v_{\text{wave}}}$$

We expect the observer (the second train) to hear a lower frequency than what is emitted (by the stationary object) since the observer is moving away, which leads to the wavefronts reaching the observer less frequently.

To get this result, we subtract the observer speed (30 m/s) from the wave speed (which, again, we'll assume is 340 m/s). That leads to a

lower number in the numerator, which makes the fraction lower. Plugging in, I get an observed frequency of 337 Hz.

Notice that we could have combined the two steps into one step if you wanted.

2. (a) For a pipe open on one end, the standing waves have a node on one end and an antinode on the other. The fundamental would look like half an “onion.” That means that only one-quarter of the wavelength is present in the pipe. Since the pipe is 50 cm long, that means the wavelength is 200 cm.

(b) The wavelength and frequency are related by $v = \lambda/T$. Plugging in 200 cm for λ and 343 m/s for v , we get a period of 0.005882 s per cycle. The frequency is defined as the inverse of the period, which gives 170 Hz (cycles per second). Notice that you need to convert the wavelength to meters to cancel the units in the speed. Also, you could have combined the definition of frequency with the wave equation to get $v = f\lambda$ and then solved it in one step.

3. The first task is to identify the critical angle, which is the minimum angle of incidence that will result in total internal reflection. At the critical angle, the angle of refraction is 90° . From Snell’s law, we have

$$n_{\text{glass}} \sin \theta_{\text{glass}} = n_{\text{air}} \sin(90^\circ)$$

where the left-hand side (incident ray) corresponds to the ray in the glass and the right-hand side (refracted ray) corresponds to the ray in the air. Since $n_{\text{air}} = 1$ and $n_{\text{glass}} = 1.523$, we can solve for θ_i to get 41° .

At location A , the beam hits the edge with an incident angle of 60° . This is more than 41° and so the beam reflects totally. By geometry, one can show that the angle of incidence at B is 30° . This is less than 41° and so the beam only partially reflects. The answer is B .

4. (a) The magnification is equal to h'/h . Since the ratio of the heights are equal to the ratio of the distances ($h'/h = -q/p$), we can just use the ratio of the distances. In this case, the image distance equals the object distance, so the magnification must be 1. However, this is a case of a real image (the image and object are not at the same place), so the image must be inverted (positive image distance) and so the magnification must be negative (-1).

(b) Be careful. To use the equation, you need the object and image distances, which are measured from the lens, not from each other. In other words, 80 cm is not the image distance, it is the distance from the object to the image. However, since $p = q$ and $q + p = 80$ cm, this means that $q = p = 40$ cm (i.e., they must each be 40 cm). Plugging in to the thin lens equation, we get

$$\begin{aligned} 1/f &= 1/(40 \text{ cm}) + 1/(40 \text{ cm}) \\ &= 2/(40 \text{ cm}) \\ &= 1/(20 \text{ cm}) \end{aligned}$$

or $f = 20$ cm.