Chapter 4.2

Q1 The delay time between you seeing the person next to you stand up and you standing up and the number density of the people i.e. how many people per unit meter. For a fixed delay time, the closer the people are the faster the wave.

Q2 There is a disturbance that travels through the lie of dominoes just as a disturbance travels through a medium when a wave is present. You can increase the speed by placing them closer together. An experiment to investigate this might be to place a number of dominoes on a line of fixed length such that the dominoes are a fixed distance *d* apart. We must give the same initial push to the first domino (for example using a pendulum that is released from a fixed height and strikes the domino at the same place. We then measure time form when the first domino is hit until the last one is hit. Dividing the fixed distance by the time taken gives the speed of the pulse. We can then repeat with a different domino separation and see how the speed depends on the separation *d*.

Q3 (a) $\lambda = \frac{v}{f} = \frac{330}{256} = 1.29 \text{ m}$. (b) $\lambda = \frac{v}{f} = \frac{330}{25\times 10^{3}} = 1.32\times 10^{-2} \text{ m}$.

Q4 See figures 2.10 and 2.12 in the textbook.

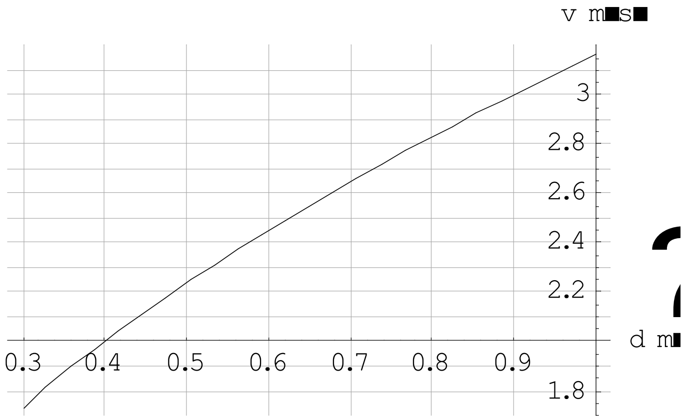
Q5 Applying the formula, $v = \sqrt{\frac{120}{\frac{0.150}{0.800}}} = 25.3 \text{ m s}^{-1}$.

Q6 (a) The speed do the wave is $v = \sqrt{\frac{50}{\frac{0.400}{20}}} = 50.0 \text{ m s}^{-1}$ and so the wavelength is $\lambda = \frac{v}{f} = \frac{50.0}{15.0} = 3.33 \text{ m}$. (b) The speed and frequency are the same and so the wavelength will be the same.

Q7 (a) The wave covers 3.00 m in 1.0 s and so the speed is $v = 3.0 \text{ m s}^{-1}$. (b) The period is 1.5 s and the frequency is $f = \frac{1}{T} = \frac{1}{1.5} = 0.67 \text{ Hz}$. (c) The wavelength is $\lambda = \frac{v}{f} = \frac{3.00}{0.67} = 4.5 \text{ m}$ and the amplitude is about 12 cm.

Q8 (a) $\lambda = \frac{v}{f} = \frac{330}{500} = 0.66 \text{ m}$. (b) The frequency in water is still 500 Hz and so $\lambda = \frac{v}{f} = \frac{1490}{500} = 2.98 \text{ m}$.

Q9 Applying the formula, $v = \sqrt{10 \times 1.0} = 3.16 \approx 3.2 \text{ m s}^{-1}$.



Q10 (a) In wave motion displacement refers to the difference in the value of a quantity such as position, pressure, density etc when the wave is present and when the wave is absent. (b) In a transverse wave the displacement is at right angles to the direction of energy transfer, in a longitudinal it is parallel to the energy transfer direction. (c) The falling stone imparts kinetic energy to the water at the point of impact and so that water moves. It will continue moving (creating many ripples) until the energy is dissipated. (d) We must recall that the intensity of a wave is proportional to the square of the amplitude. The amplitude will decrease for two reasons: first, some energy is bound to be dissipated as the wave moves away and so the amplitude has to decrease. Second, even in the absence of any energy losses, the amplitude will still decrease because the wavefronts get bigger as they move away from the point of impact of the ripple. The energy carried by the wave is now distributed on a longer wavefront and so the energy per unit wavefront length decreases. The amplitude must then decrease as well.

Q11 In 3.2 s the pulse has a covered double the distance to the submarine. Hence, $d = vt = 1500 \times 1.6 = 2400 \text{ m}$. The wavelength is $\lambda = \frac{v}{f} = \frac{1500}{30 \times 10^3} = 0.050 \text{ m}$. The period is $T = \frac{1}{f} = \frac{1}{30 \times 10^3} = 3.33 \times 10^{-5} \text{ s}$ and so in 1 ms we have $\frac{10^{-3}}{3.33 \times 10^{-5}} = 30$ full waves.

Q12 Imagine drawing the same wave slightly displaced to the right. Then the points from left to right move down, down and up.

Q13 The answers will now be reversed, up, up and down.

Q14 The diagram is shown in the answers in the textbook.

Q15 (a) The amplitude is the maximum displacement and so is 0.6 cm. (b) The wavelength is the crest to crest distance and so is 4.0 m. (c) The crests moved forward a distance of 1.0 m in 0.20 s and so the wave speed is $v = \frac{1.0}{0.20} = 5.0 \text{ m s}^{-1}$. (d) The frequency is therefore $f = \frac{v}{\lambda} = \frac{5.0}{4.0} = 1.25 \text{ Hz}$. (e) No, both would look the same.

Q16 As shown in the answers in the textbook.

Q17 (a) The wavelength is 0.40 m and so the frequency is $f = \frac{v}{\lambda} = \frac{340}{0.40} = 850 \text{ Hz}$. (b) A compression is at $x = 0.30 \text{ m}$ since particles to the right of it have negative displacement and so move towards it (i.e. to the left) and particles to the left of it have positive displacement and so move towards as well (i.e. to the right). Similarly, $x = 0.10 \text{ m}$ is the center of a rarefaction. (c) This is a much harder question to answer than (b). Centers of compressions and rarefactions will be found whenever the displacement is zero so in this case the candidates are at $t = 0.10 \text{ s}$ and $t = 0.69 \text{ s}$ .The equation giving the displacement of the wave is $y = A\sin\left(2\pi(\frac{t}{T} - \frac{x}{\lambda})\right)$. When the displacement is zero, we have that $\sin\left(2\pi(\frac{t}{T} - \frac{x}{\lambda})\right) = 0$ and so $2\pi(\frac{t}{T} - \frac{x}{\lambda}) = \begin{cases} 0, 2\pi, 4\pi, 6\pi, ... \\ \pi, 3\pi, 5\pi, ... \end{cases}$. The derivative of the displacement with respect to time is $\frac{dy}{dt} = \frac{2\pi A}{T}\cos\left(2\pi(\frac{t}{T} - \frac{x}{\lambda})\right)$ and so when $y = 0$

$$\frac{dy}{dt} = \frac{2\pi A}{T}\cos\left(2\pi(\frac{t}{T} - \frac{x}{\lambda})\right) = \begin{cases} > 0 & 0, 2\pi, 4\pi, 6\pi, ... \\ < 0 & \pi, 3\pi, 5\pi, ... \end{cases} . \qquad [1]$$

Now let us consider a point where the displacement is zero. If this point is a distance x from the origin. We need to know the displacement of points immediately to the right and left of this point. So points to the right will be a distance of $x + \varepsilon$ and points to the left a distance of $x - \varepsilon$ where ε is a small positive number. Then,

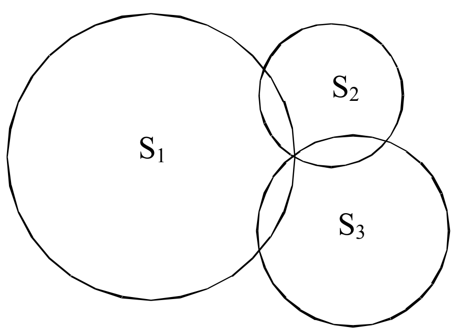
$$\begin{aligned} y\big|_{x\pm\varepsilon} &= A\sin\left(2\pi(\frac{t}{T} - \frac{x\pm\varepsilon}{\lambda})\right) = A\sin\left(2\pi(\frac{t}{T} - \frac{x}{\lambda}) \mp \frac{2\pi\varepsilon}{\lambda}\right) \\ &= A\sin\left(2\pi(\frac{t}{T} - \frac{x}{\lambda})\right)\cos\frac{2\pi\varepsilon}{\lambda} \mp A\cos\left(2\pi(\frac{t}{T} - \frac{x}{\lambda})\right)\sin\frac{2\pi\varepsilon}{\lambda} \\ &= 0 \mp A\cos\left(2\pi(\frac{t}{T} - \frac{x}{\lambda})\right)\sin\frac{2\pi\varepsilon}{\lambda} \\ &= \mp\frac{2\pi\varepsilon A}{\lambda}\cos\left(2\pi(\frac{t}{T} - \frac{x}{\lambda})\right) \end{aligned}$$

where we used the small angle approximations $\sin\frac{2\pi\varepsilon}{\lambda} \approx \frac{2\pi\varepsilon}{\lambda}$ and $\cos\frac{2\pi\varepsilon}{\lambda} \approx 1$. Now when the displacement is zero and $\frac{dy}{dt} > 0$, $\cos\left(2\pi(\frac{t}{T} - \frac{x}{\lambda})\right) > 0$ and so $y\big|_{x\pm\varepsilon} = \mp\frac{2\pi\varepsilon A}{\lambda}$.
This means points to the right have negative displacement and move to the left and points to the left have positive displacement and move to the right. Hence points where $y = 0$ and $\frac{dy}{dt} > 0$ correspond to compressions, like for example at $t = 0.10$ s and working similarly for points such as at $t = 0.69$ s we have a rarefaction.

Q18 See figures 2.1 and 2.2 in the text.

Q19 See textbook pages 244-5.

Q20 Differences include different arrival times of the signals and signals of different intensity.



From the diagram it is impossible to determine the epicenter with only two stations since the two circles in general intersect at two points. You need a third station to determine which one of the two.