Answers to Problems: Chapter 2

2.1

$$V = f\lambda$$

$$V = 1400\,\mathrm{m/s} = 10\,\mathrm{Hz}(\lambda)$$

$$\lambda = 140\,\mathrm{m}$$

$V = 1400\,\mathrm{m/s}$ and $f = 100\,\mathrm{Hz}$; $\lambda = 14\,\mathrm{m}$

2.2

$$\lambda = 450\,\mathrm{m}$$

$$\lambda = 45\,\mathrm{m}$$

2.3

$$V_P = \left(\frac{E(1-\mu)}{\rho(1-2\mu)(1+\mu)}\right)^{1/2} = \left(\frac{0.39\times10^{11}\,N/m^2(1-0.11)}{2.60\,\mathrm{g/cm^3}(1-2(0.11))(1+0.11)}\right)^{1/2}$$

$$V_P = \left(\frac{0.3471\times10^{11}\,\mathrm{N/m^2}}{2.2511\,\mathrm{g/cm^3}}\right)^{1/2}$$

$$V_P = \left(\frac{1.542\times10^{10}\,\mathrm{N\cdot cm^3}}{\mathrm{m^2\cdot g}}\cdot\frac{10^5\,\mathrm{dynes}}{\mathrm{N}}\cdot\frac{\mathrm{g\cdot cm/s^2}}{\mathrm{dyne}}\cdot\frac{\mathrm{m^2}}{10^4\,\mathrm{cm^2}}\right)^{1/2}$$

$$V_P = \left(\frac{1.5419\times10^{11}\,\mathrm{cm^2}}{\mathrm{s^2}}\right)^{1/2} = 3.927\times10^5\,\mathrm{cm/s} = 3.927\times10^3\,\mathrm{m/s} = 3927\,\mathrm{m/s}$$

2.4

$V_S = 1227$ m/s

2.5

$V_S = 1547$ m/s
$V_R = 0.9V_S = 1392$ m/s

2.6

Analysis of Equation 2.11 suggests that *E* most directly affects velocity values. The following table supports this assertion given the range of normal variation of the pertinent variables.

Density	Young's Modulus	Poisson's Ratio	Vp
ρ	E	μ	(m/s)
2.00	0.120	0.040	2454
2.00	0.120	0.300	2842
2.00	1.100	0.040	7429
2.00	1.100	0.300	8605
3.00	0.120	0.040	2003
3.00	0.120	0.300	2320
3.00	1.100	0.040	6065
3.00	1.100	0.300	7026

2.7

$$\text{time} = \frac{\text{distance}}{\text{velocity}}$$

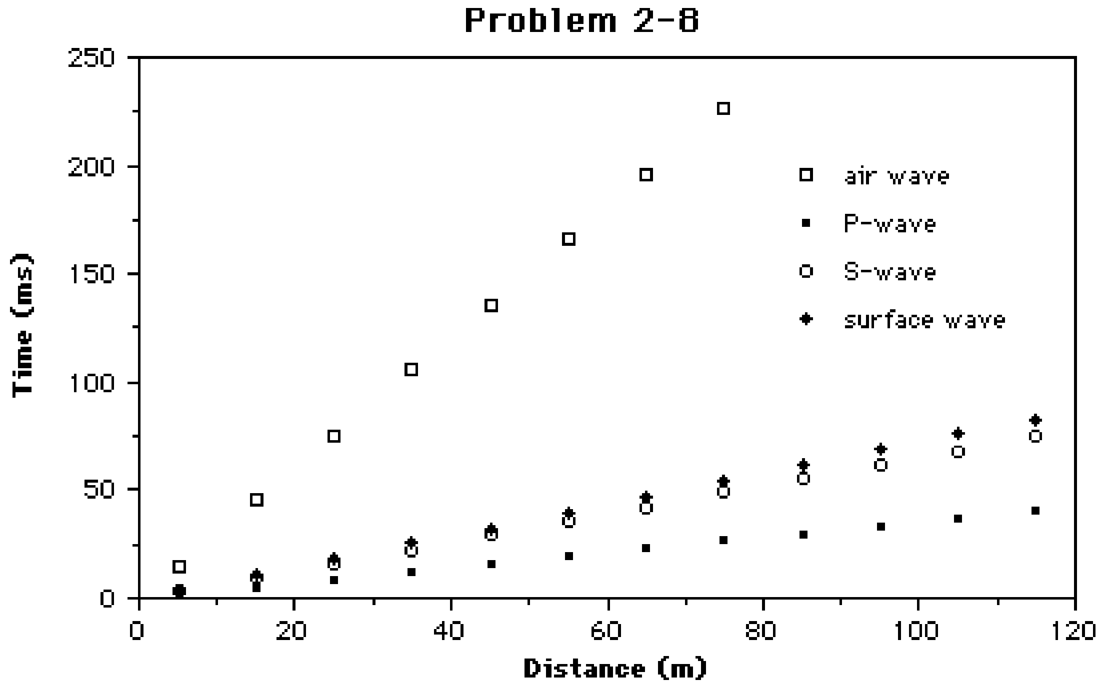
$$\text{time}_{\text{air}} = \frac{50\,\text{m}}{331.5\,\text{m/s}} = 0.151\,\text{s} = 151\,\text{m s}$$

$$\text{time}_{\text{direct P}} = \frac{50\,\text{m}}{2488\,\text{m/s}} = 0.020\,\text{s} = 20\,\text{ms}$$

$$\text{time}_{\text{Rayleigh}} = \frac{50\,\text{m}}{(0.9)1702\,\text{m/s}} = 0.033\,\text{s} = 33\,\text{ms}$$

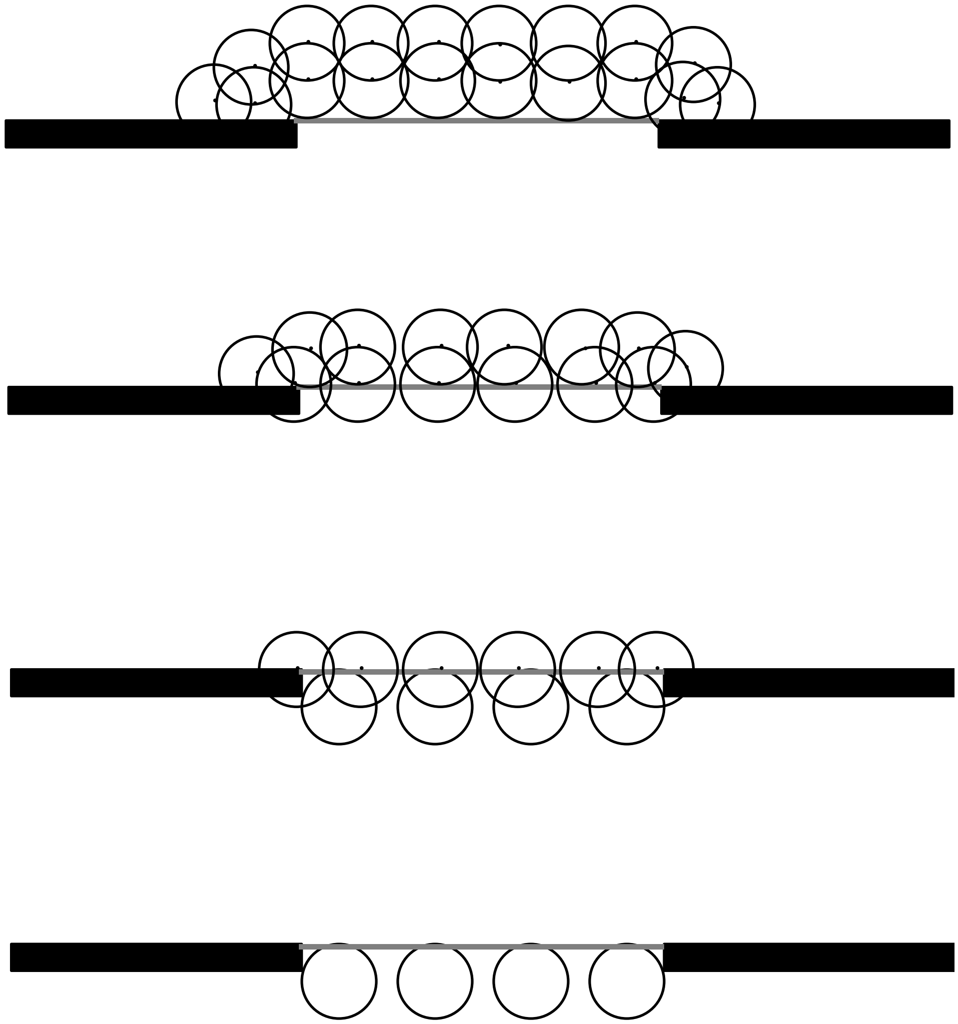
2.8

V_{P} = 2829 m/s; V_{S} = 1539 m/s; V_{Rayleigh} = 1385 m/s; V_{air} = 331.5 m/s.



2.9

The drawing below, moving from bottom to top, illustrates successive wavelets emanating from the front of the last wave front. This illustrates in a general way the effect portrayed in Figure 2.18.



2.10

This is straightforward because we need only substitute the relevant variables in Equations 2.19–2.21.

$$\sin\theta_{rfr_S} = \frac{d_2}{AY} \quad \text{and} \quad \sin\theta_{i_P} = \frac{d_1}{AY}$$

$$d_1 = t_1 V_{1_P} \qquad \text{and} \qquad d_2 = t_1 V_{2_S}$$

$$AY = \frac{t_1 V_{1_P}}{\sin\theta_{i_P}} = \frac{t_1 V_{2_S}}{\sin\theta_{rfr_S}} \quad \text{and} \quad \frac{\sin\theta_{i_P}}{\sin\theta_{rfr_S}} = \frac{V_{1_P}}{V_{2_S}}.$$

2.11

This also is straightforward because we need only substitute the relevant quantities in Figure 2.14 and carry these substitutions through Equations 2.22–2.25. These substitutions are as follows:

$$\theta_1 \rightarrow \theta_{i_S},\ \theta_2 \rightarrow \theta_{rfr_P},\ V_1 \rightarrow V_{1_S},\ \text{and}\ V_2 \rightarrow V_{2_P}$$

Then

$$\frac{\sin\theta_{i_S}}{\sin\theta_{rfr_P}} = \frac{V_{1_S}}{V_{2_P}}.$$

2.12

$$\frac{\sin\theta_{i_P}}{\sin\theta_{rfr_P}} = \frac{V_{1_P}}{V_{2_P}}$$

$$\frac{\sin 20^\circ}{\sin\theta_{rfr_P}} = \frac{331.5\,\text{m/s}}{500\,\text{m/s}}$$

$$\theta_{rfr_P} = 31^\circ$$

$$\theta_{rfr_S} = 12^\circ$$

2.13

$$\theta_{rfr_P} = 78^\circ$$

$$\theta_{rfr_S} = 29^\circ$$

2.14

$$\theta_{rfr_P} = 28^\circ$$

$$\theta_{rfr_S} = 10^\circ$$

2.15

$$\theta_{rfr_P} = 16^\circ$$

2.16

(a) The angle of refraction increases as the angle of incidence increases. The angle of refraction always is greater than the angle of incidence until the critical angle for refraction is reached, after which total reflection occurs.

(b) Although the angle of refraction increases as the angle of incidence increases, the angle of refraction always is less than the angle of incidence.

2.17

$$\theta_{ic_P} = \sin^{-1}\left(\frac{V_{1_P}}{V_{2_P}}\right) = \sin^{-1}\left(\frac{1200\,\text{m/s}}{3800\,\text{m/s}}\right) = 18.4^\circ$$

$$\theta_{ic_c} = \sin^{-1}\left(\frac{V_{1_P}}{V_{2_S}}\right) = \sin^{-1}\left(\frac{1200\,\text{m/s}}{1900\,\text{m/s}}\right) = 39.2^\circ$$

2.18

$$\tan\theta_{ic} = \frac{x_{crit}/2}{h_1}$$

and, since $\sin\theta_{ic} = \dfrac{V_1}{V_2}$,

$$\tan\left(\sin^{-1}\left(\frac{V_1}{V_2}\right)\right) = \frac{x_{crit}/2}{h_1}$$

and

$$x_{crit} = 2h_1 \tan\left(\sin^{-1}\left(\frac{V_1}{V_2}\right)\right).$$