Chapter 4.3
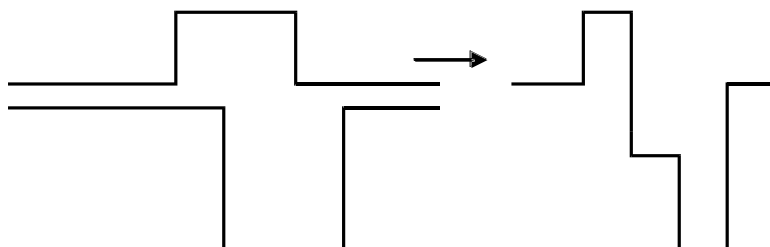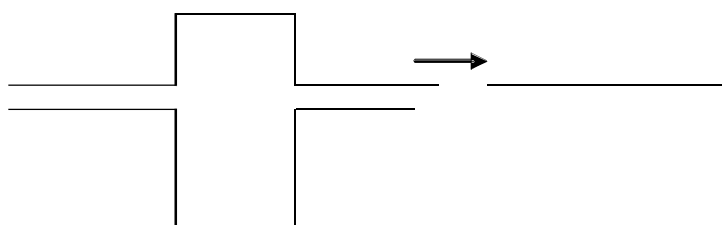
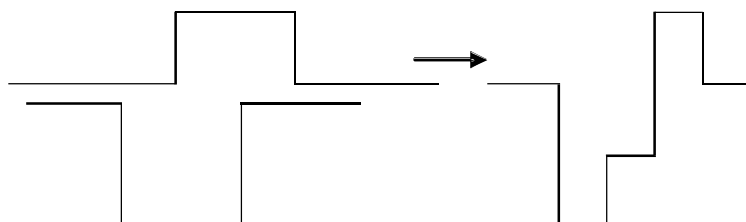Q1 and Q2 give the obvious diagrams in the answers in the textbook.

Q3 The pulses move with a speed of 2.0 cm s^{-1} relative to each other and so:
at 0.5 s they overlap by 1.0 cm.

At 1.0 s they overlap by 2 cm:

At 1.5 s

Q4 Adding in a straightforward way gives the graph in the answers in the textbook.

Q5 (a) From $1.00 \times \sin 38° = 1.583 \times \sin\theta_2$ we find

$$\sin\theta_2 = \frac{1.00 \times \sin 38°}{1.583} \Rightarrow \theta_2 = \sin^{-1} 0.3889 = 22.9°. \text{ (b)}$$

$$n = \frac{c}{c_g} \Rightarrow c_g = \frac{c}{n} = \frac{3.0 \times 10^8}{1.583} = 1.9 \times 10^8 \text{ m s}^{-1}. \text{ (c) The frequency in water is the same}$$
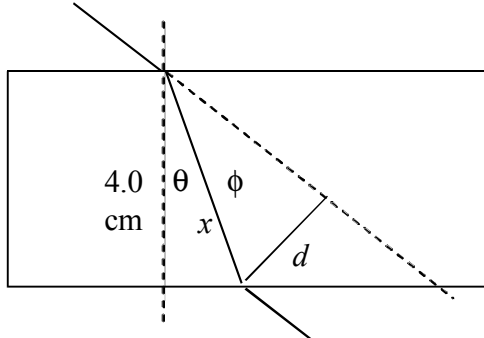
as that in air and so $\lambda_g = \dfrac{\lambda_a}{n} = \dfrac{6.8 \times 10^{-7}}{1.583} = 4.3 \times 10^{-7}$ m .

Q6 (a) $t = \dfrac{s}{c} = \dfrac{3.0}{3.0 \times 10^8} = 1.0 \times 10^{-8}$ s . (b) In this time,

$1.0 \times 10^{-8} \times 6.0 \times 10^{14} = 6.0 \times 10^6$ full waves have been emitted. (Or, the wavelength

is $\lambda = \dfrac{3.0 \times 10^8}{6.0 \times 10^{14}} = 5.0 \times 10^{-7}$ m and in a length of 3.0 m we can fit

$\dfrac{3.0}{5.0 \times 10^{-7}} = 6.0 \times 10^6$ full waves.)

Q7 First we find the angle of refraction (angle θ in the diagram).

$1.00 \times \sin 40° = 1.450 \times \sin\theta$, hence $\theta = 26.3°$. This means that
$x = \dfrac{4.0}{\cos 26.3°} = 4.46$ cm . Now $\varphi = 40°2 - 26.3° = 13.7°$ and so
$d = 4.46 \times \sin 13.7° = 1.06$ cm .

Q8 At the air – glass boundary, $1.00 \times \sin 45° = 1.420 \times \sin\theta$ hence $\theta = 29.9°$. At the glass – plastic boundary, $1.420 \times \sin 29.9° = 1.350 \times \sin\varphi$ hence $\varphi = 31.6°$. At the plastic – air boundary the ray exits at $\omega = 45°$ as expected:
$1.350 \times \sin 31.6° = 1.00 \times \sin\omega$, hence $\omega = 45°$. This gives the diagram in the answers in the textbook.

Q9 If the ray hits low enough on the prism side it will be refracted so that it then hits the lower side as shown.
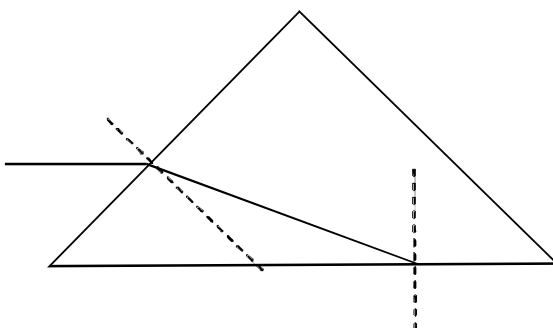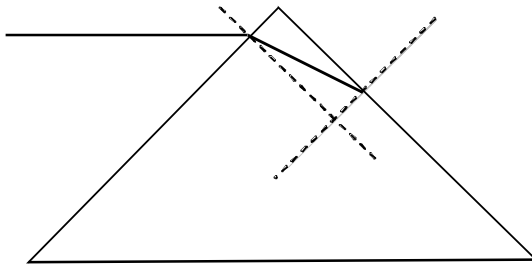

The angle of incidence is $45°$ and so the angle of refraction at the first air – glass boundary is given by $1.00 \times \sin 45° = 1.50 \times \sin\theta$ hence $\theta = 28.1°$. The angle of incidence at the next refraction point is found from $90° - (180° - 135° - 28.1°) = 73.1°$. Attempting to find the refraction angle fails because we get a sine of the refracted angle larger than 1 which is impossible. This means that the ray totally internally reflects – there is no refracted ray. The diagram then continues as shown below.
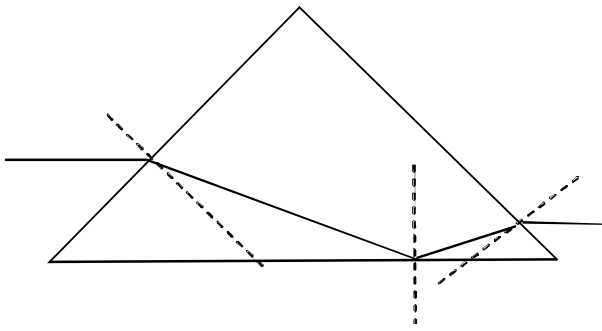
The new angle of incidence is $180° - 135° - (90° - 73.1°) = 28.1°$. Hence the ray refracts out of the prism at an angle $1.00 \times \sin\omega = 1.50 \times \sin 28.1°$, hence $\omega = 45°$. The ray continues parallel to its original direction.

However, if the ray hits high enough on the prism side it will be refracted so that it then hits the opposite side as shown.

The angle of incidence is $45°$ and so the angle of refraction at the first air – glass boundary is given by $1.00 \times \sin 45° = 1.50 \times \sin\theta$ hence $\theta = 28.1°$. The angle of incidence at the next refraction point is found from $90° - 28.1° = 61.9°$. The ray will then suffer total internal reflection and proceed as follows:
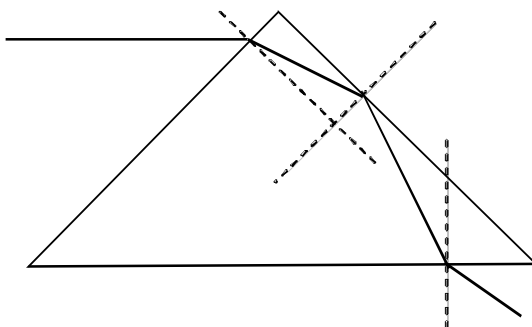
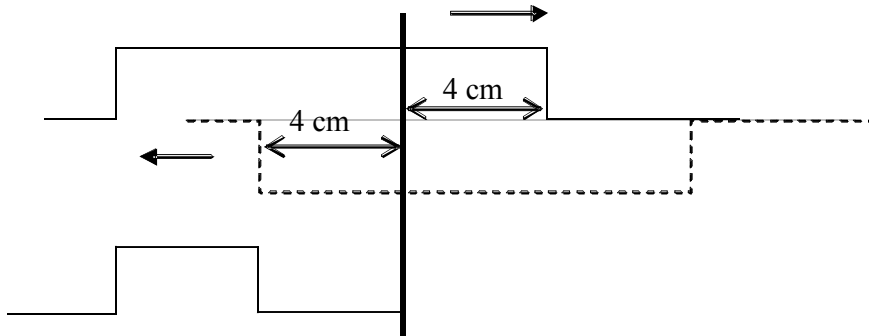The angle of incidence at the next refraction point is
$180° - 135° - (90° - 61.9°) = 16.9°$ and so the ray exits the prism at an angle given by
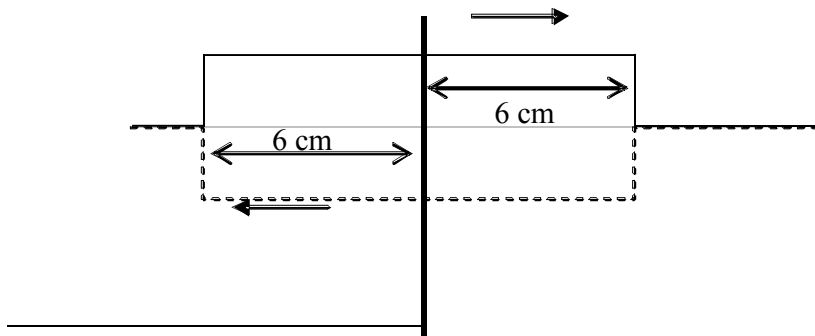$1.00 \times \sin\omega = 1.50 \times \sin 16.9°$, i.e. $\omega = 25.9°$.

Q10 Let θ be the angle of incidence from air. The angle of refraction will be larger than θ and so as θ increases the angle of refraction will become $90°$ and so will not enter water. This happens when $\dfrac{\sin\theta}{340} = \dfrac{\sin 90°}{1500} \Rightarrow \theta = \sin^{-1}\dfrac{340}{1500} = 13.1°$.

Q11 We make use of the ideal of the imaginary pulse that comes out of the wall and then apply the principle of superposition.
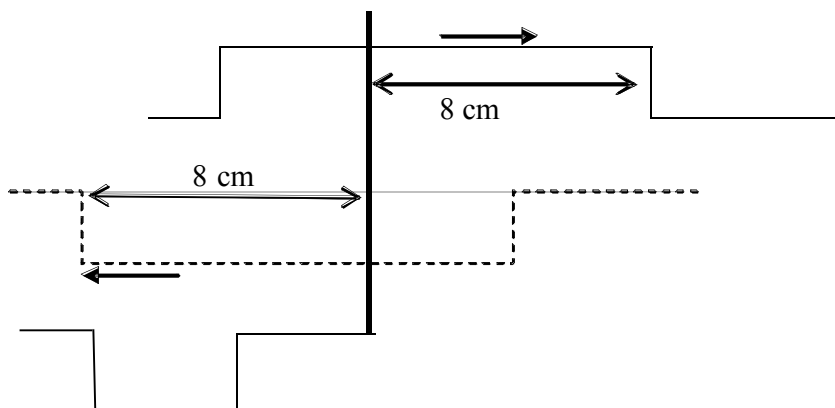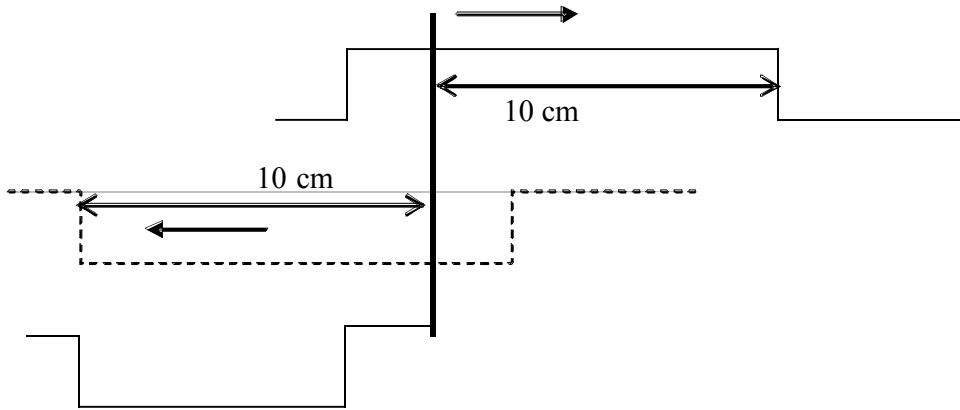
$t = 1.0$ ms

4 cm

4 cm

4 cm

$t = 1.5$ ms
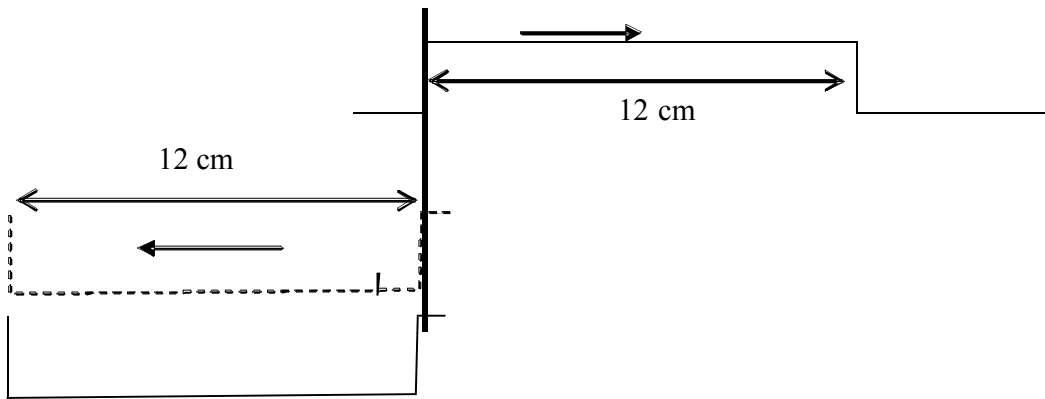

6 cm

6 cm

$t = 2.0$ ms

8 cm

8 cm

t = 2.5 ms

10 cm

10 cm

t = 3.0 ms

12 cm

12 cm

t = 4.0 ms

4 cm