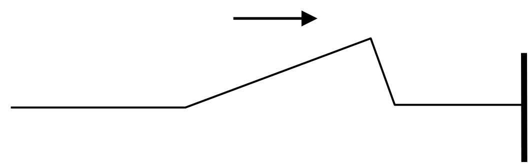
Problem of the week

Wave phenomena (SL&HL)

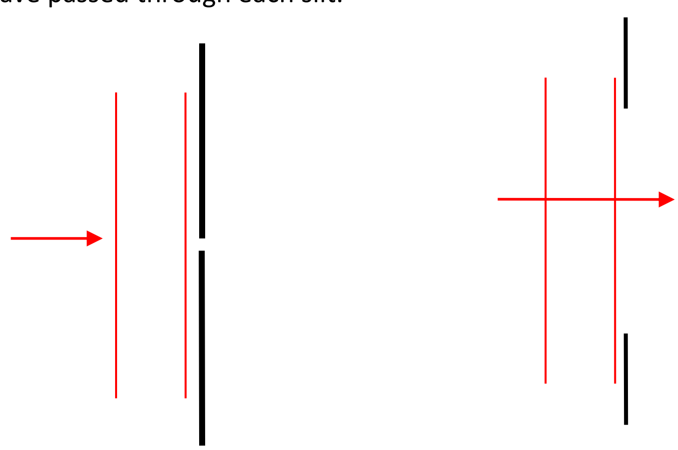
(a) A pulse on a string approaches the fixed right end of the string.



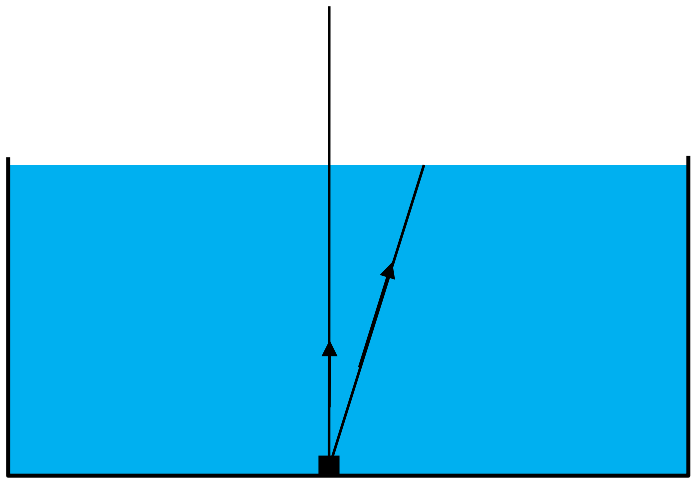
(i) Draw the reflected pulse.

(ii) Explain your drawing.

(b) Planar wavefronts are approaching two slits a shown. In each case, draw two wavefronts after they have passed through each slit.



(c) A small object is at the bottom of a container full of water. Two rays are shown leaving the object. One ray is shown extending into air.

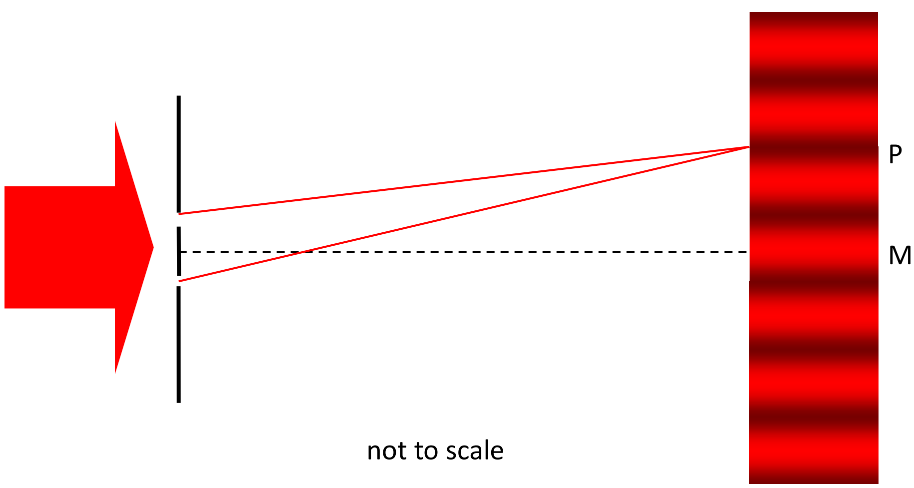


(i) Draw a line to extend the other ray in air.

(ii) Use the diagram to explain why, to an observer looking from above, the depth of the water appears smaller than the actual depth.

(iii) The ray makes an angle of 15.0° with the vertical. The depth of the water is 1.20 m. The refractive index of water is 1.33. Estimate the apparent depth of the water.

(d) The diagram shows the two-slit interference pattern formed on a screen for two very narrow slits. M is the mid-point of the pattern directly across from the mid-point of the slits. The separation of the slits is 0.12 mm and the distance to the screen is 1.4 m.



(i) Discuss how the maximum at M is formed.

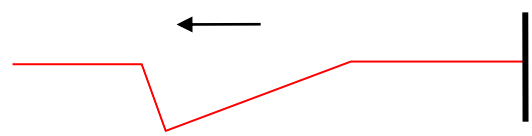
(ii) State the path difference between the rays arriving at P.

(iii) The distance MP along the screen is 9.0 mm. Determine the wavelength of light.

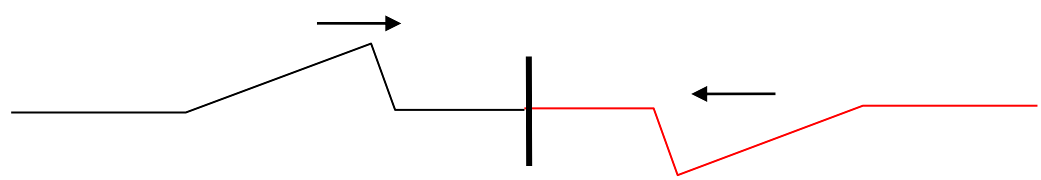
Answers

(a)

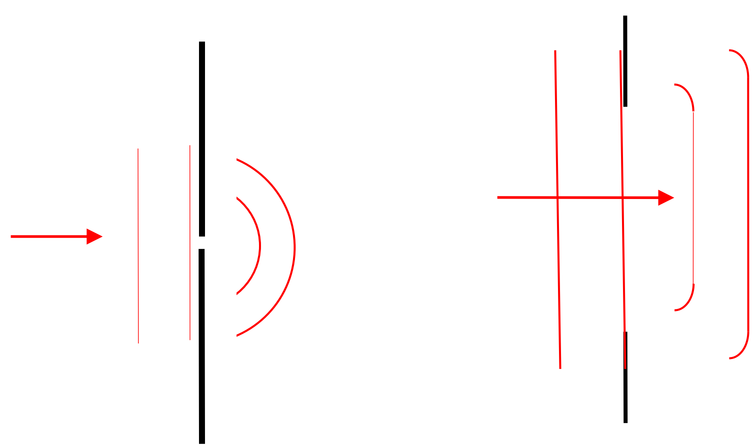
(i)



(ii) Reflection can be thought of as the pulse disappearing into the right of the support and an imaginary pulse from the right of the support appearing to the left of the support as the reflected pulse. The two pulses (real and imaginary) are supposed to superpose when they meet. The point of the string at the support must stay fixed and not move. This will happen if the imaginary pulse has the shape that it does.



(b)



$\lambda >> b$

lots of diffraction

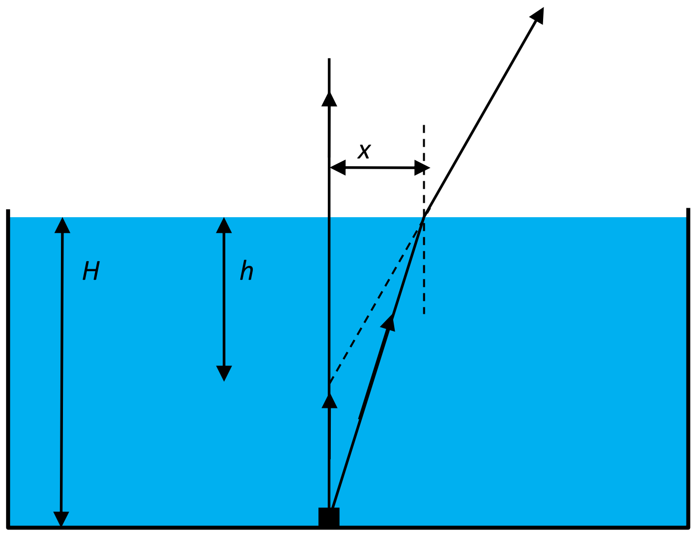
$\lambda << b$

little diffraction

(c)

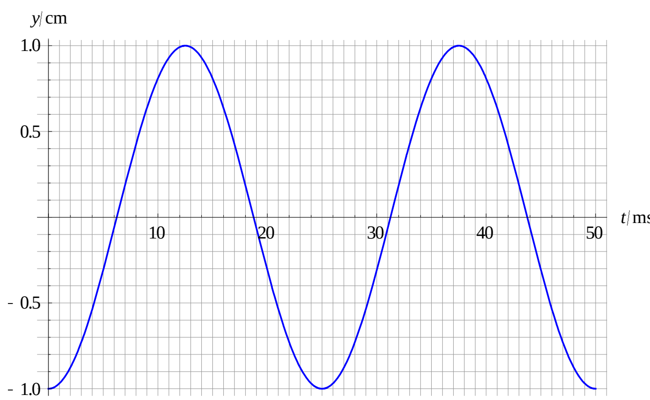
(i) Ray shown in diagram.

(ii) Ray extended intersects vertical ray at a lower depth than the actual depth.



(iii) Angle of refraction in air: $1.33\times\sin 15^{\circ}=1.00\times\sin\theta \Rightarrow \sin\theta=0.34423 \Rightarrow \theta=20.13^{\circ}$.

$\tan 15^{\circ}=\dfrac{x}{H}$ and $\tan 20.13^{\circ}=\dfrac{x}{h}$. Hence $h=H\times\dfrac{\tan 15.0^{\circ}}{\tan 20.13^{\circ}}=0.877\text{ m}$.



(d)

(i) M is equidistant from the slits, so the path difference is zero. The waves leaving the slits are coherent because they come from the same wavefront and so they meet at M peak to peak leading to constructive interference.

(ii) 1.5λ

(iii) $\dfrac{3}{2}s=9.0 \Rightarrow s=6.0\text{ mm}$. $s=\dfrac{\lambda D}{d} \Rightarrow \lambda=\dfrac{sd}{D}=\dfrac{6.0\times10^{-3}\times0.12\times10^{-3}}{1.4}=5.14\times10^{-7}\text{ m}$