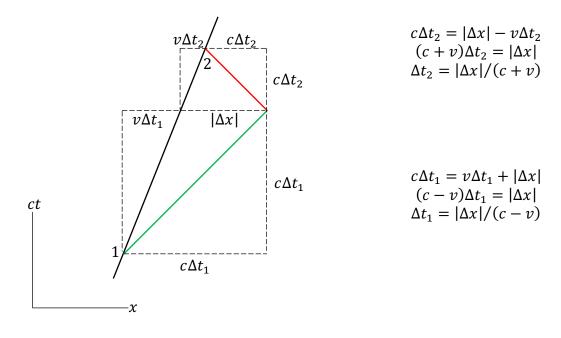


Retarded wave leaves particle when it is at 1 and arrives at (x, y) at time t Advanced wave leaves particle when it is at 2 and arrives at (x, y) at time t

(x_p, y_p)	particle position at time t
(x,y)	point on wave at time t
Δx	$x-x_p$
Δy	$y-y_p$
t_1	time when particle was at position 1
t_2	time when particle will be at position 2
Δt_1	$t-t_1$
Δt_2	$t_2 - t$
x_1	x position of particle at time $1 = x_p - v\Delta t_1$
<i>x</i> ₂	x position of particle at time $2 = x_p + v\Delta t_2$

 $\Delta y = 0$ (linear)



$$(c\Delta t_{1})^{2} = (\Delta y)^{2} + (v\Delta t_{1} + \Delta x)^{2} = (\Delta y)^{2} + v^{2}(\Delta t_{1})^{2} + 2v\Delta t_{1}\Delta x + (\Delta x)^{2}$$

$$c^{2}(\Delta t_{1})^{2} - v^{2}(\Delta t_{1})^{2} = (\Delta y)^{2} + 2v\Delta t_{1}\Delta x + (\Delta x)^{2}$$

$$(c^{2} - v^{2})(\Delta t_{1})^{2} - 2v\Delta x\Delta t_{1} - (\Delta y)^{2} - (\Delta x)^{2} = 0$$

$$(\Delta t_{1})^{2} - \frac{2v\Delta x}{(c^{2} - v^{2})}\Delta t_{1} - \frac{(\Delta y)^{2} + (\Delta x)^{2}}{(c^{2} - v^{2})} = 0$$

$$\Delta t_{1} = \left\{ \frac{2v\Delta x}{(c^{2} - v^{2})} \pm \sqrt{\left[\frac{2v\Delta x}{(c^{2} - v^{2})}\right]^{2} + 4\frac{(\Delta y)^{2} + (\Delta x)^{2}}{(c^{2} - v^{2})}} \right\} / 2$$

$$= \frac{1}{(c^{2} - v^{2})} \left[v\Delta x \pm \sqrt{v^{2}(\Delta x)^{2} + (c^{2} - v^{2})[(\Delta y)^{2} + (\Delta x)^{2}]} \right]$$

$$= \frac{1}{(c^{2} - v^{2})} \left[v\Delta x \pm \sqrt{v^{2}(\Delta x)^{2} + c^{2}(\Delta y)^{2} - v^{2}(\Delta y)^{2} + c^{2}(\Delta x)^{2} - v^{2}(\Delta x)^{2}} \right]$$

$$\pm \Rightarrow +$$

$$\Delta t_1 = \frac{1}{(c^2 - v^2)} \left\{ v(x - x_p) + \sqrt{(c^2 - v^2)(y - y_p)^2 + c^2(x - x_p)^2} \right\}$$

$$\Delta x = 0 \implies \Delta t_1 = \frac{\sqrt{(c^2 - v^2)(\Delta y)^2}}{(c^2 - v^2)} = \frac{\Delta y}{\sqrt{c^2 - v^2}}$$
$$(\Delta t_1)^2 = \frac{(\Delta y)^2}{c^2 - v^2}$$
$$c^2 (\Delta t_1)^2 - v^2 (\Delta t_1)^2 = (\Delta y)^2$$
$$(c\Delta t_1)^2 = (v\Delta t_1)^2 + (\Delta y)^2 \checkmark$$

$$v = 0 \implies \Delta t_1 = \frac{1}{c^2} \left[\sqrt{c^2 (\Delta y)^2 + c^2 (\Delta x)^2} \right]$$
$$(\Delta t_1)^2 = \frac{1}{c^4} [c^2 (\Delta y)^2 + c^2 (\Delta x)^2]$$
$$(c\Delta t_1)^2 = (\Delta y)^2 + (\Delta x)^2 \quad \checkmark$$

$$\Delta y = 0 \implies \Delta t_1 = \frac{1}{(c^2 - v^2)} \left[v \Delta x + \sqrt{c^2 (\Delta x)^2} \right]$$
$$\Delta t_1 = \frac{v |\Delta x| + c |\Delta x|}{(c + v)(c - v)} = \frac{\Delta x}{c - v} \checkmark$$

$$(c\Delta t_2)^2 = (\Delta y)^2 + (v\Delta t_2 - \Delta x)^2 = (\Delta y)^2 + v^2(\Delta t_2)^2 - 2v\Delta t_2\Delta x + (\Delta x)^2$$

$$c^2(\Delta t_2)^2 - v^2(\Delta t_2)^2 = (\Delta y)^2 - 2v\Delta t_2\Delta x + (\Delta x)^2$$

$$(c^2 - v^2)(\Delta t_2)^2 + 2v\Delta x\Delta t_2 - (\Delta y)^2 - (\Delta x)^2 = 0$$

$$(\Delta t_2)^2 + \frac{2v\Delta x}{(c^2 - v^2)}\Delta t_2 - \frac{(\Delta y)^2 + (\Delta x)^2}{(c^2 - v^2)} = 0$$

$$\Delta t_2 = \left\{ \frac{-2v\Delta x}{(c^2 - v^2)} \pm \sqrt{\left[\frac{2v\Delta x}{(c^2 - v^2)}\right]^2 + 4\frac{(\Delta y)^2 + (\Delta x)^2}{(c^2 - v^2)}} \right\} / 2$$

$$= \frac{1}{(c^2 - v^2)} \left[-v\Delta x \pm \sqrt{v^2(\Delta x)^2 + (c^2 - v^2)[(\Delta y)^2 + (\Delta x)^2]} \right]$$

$$= \frac{1}{(c^2 - v^2)} \left[-v\Delta x \pm \sqrt{v^2(\Delta x)^2 + c^2(\Delta y)^2 - v^2(\Delta y)^2 + c^2(\Delta x)^2} - v^2(\Delta x)^2} \right]$$

$$\pm \Rightarrow +$$

$$\Delta t_2 = \frac{1}{(c^2 - v^2)} \left\{ -v(x - x_p) + \sqrt{(c^2 - v^2)(y - y_p)^2 + c^2(x - x_p)^2} \right\}$$

$$\Delta x = 0 \implies \Delta t_2 = \frac{\sqrt{(c^2 - v^2)(\Delta y)^2}}{(c^2 - v^2)} = \frac{\Delta y}{\sqrt{c^2 - v^2}}$$
$$(\Delta t_2)^2 = \frac{(\Delta y)^2}{c^2 - v^2}$$
$$c^2 (\Delta t_2)^2 - v^2 (\Delta t_2)^2 = (\Delta y)^2$$
$$(c\Delta t_2)^2 = (v\Delta t_2)^2 + (\Delta y)^2 \checkmark$$

$$v = 0 \implies \Delta t_2 = \frac{1}{c^2} \left[\sqrt{c^2 (\Delta y)^2 + c^2 (\Delta x)^2} \right]$$
$$(\Delta t_2)^2 = \frac{1}{c^4} \left[c^2 (\Delta y)^2 + c^2 (\Delta x)^2 \right]$$
$$(c\Delta t_2)^2 = (\Delta y)^2 + (\Delta x)^2 \quad \checkmark$$

$$\Delta y = 0 \implies \Delta t_2 = \frac{1}{(c^2 - v^2)} \left[-v\Delta x + \sqrt{c^2 (\Delta x)^2} \right]$$
$$\Delta t_2 = \frac{-v|\Delta x| + c|\Delta x|}{(c+v)(c-v)} = \frac{\Delta x}{c+v} \checkmark$$