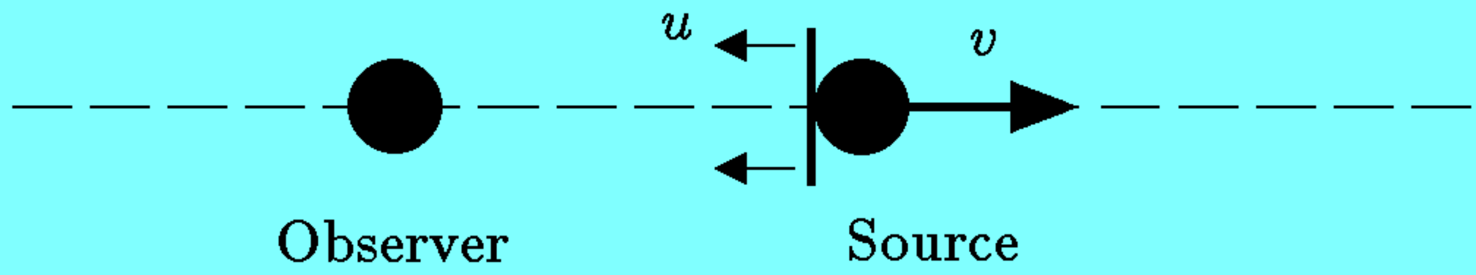
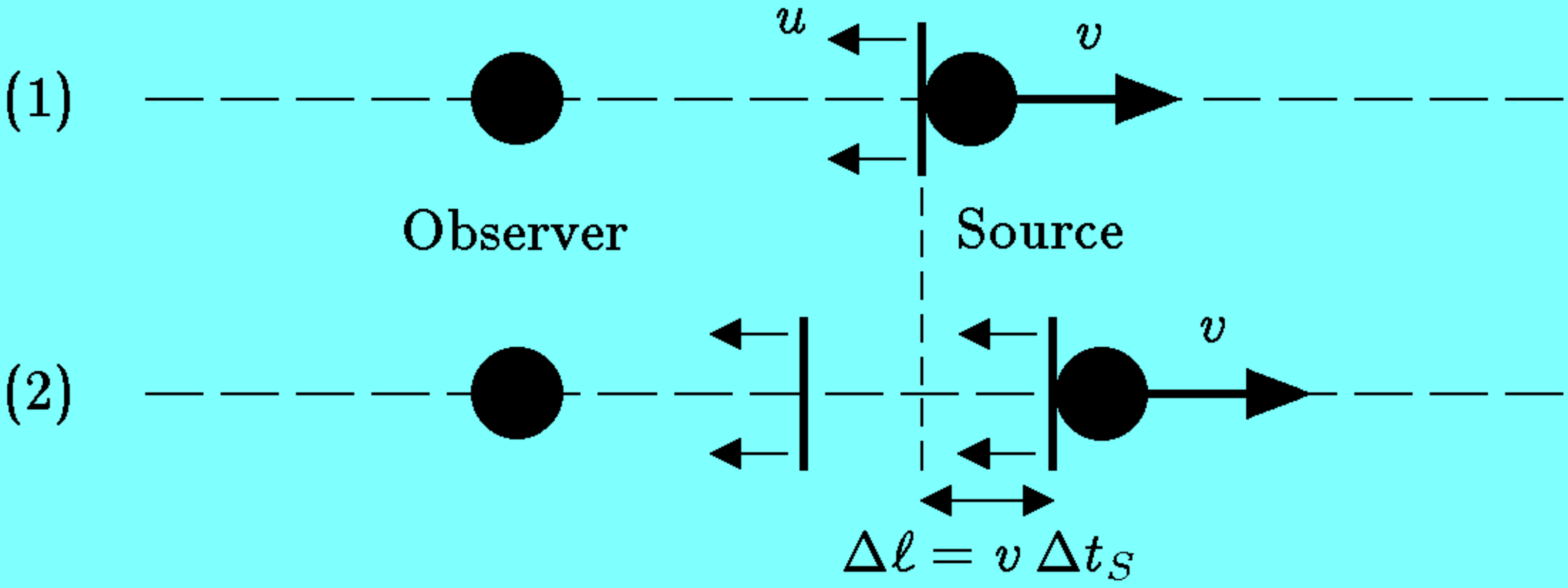
8.286 Lecture 3
September 12, 2013

THE DOPPLER EFFECT and SPECIAL RELATIVITY

(1)




(1)
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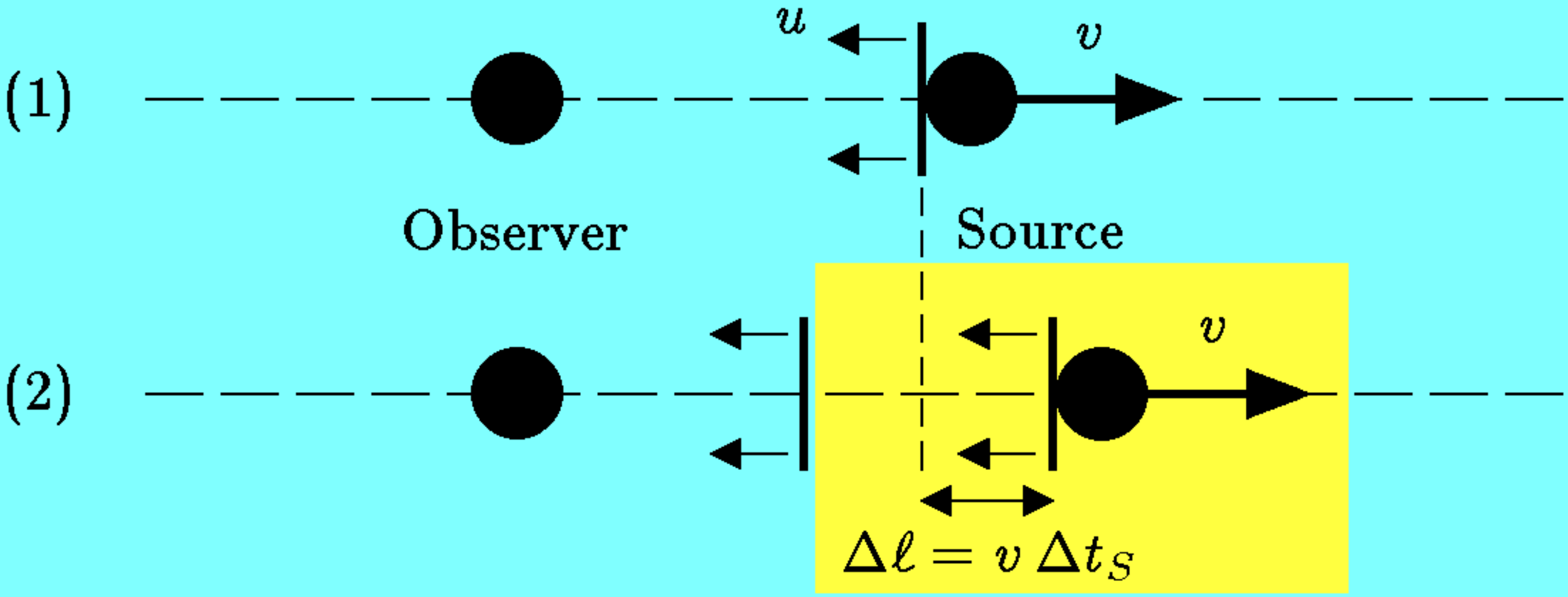
Observer
Source
(2)
v
$\Delta\ell = v\,\Delta t_S$



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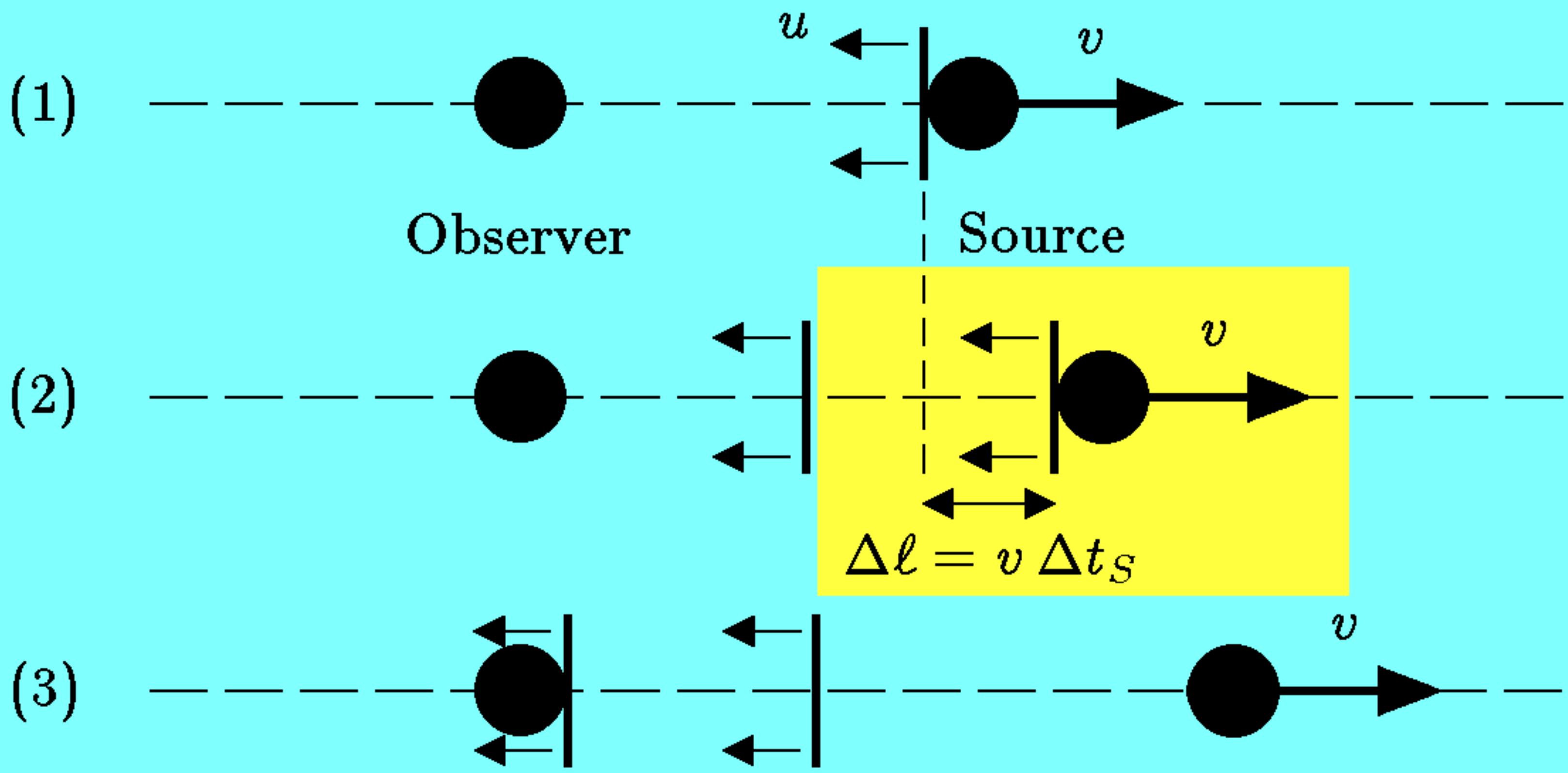
$\Delta\ell = v\,\Delta t_S$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$\Delta\ell = v\,\Delta t_S$
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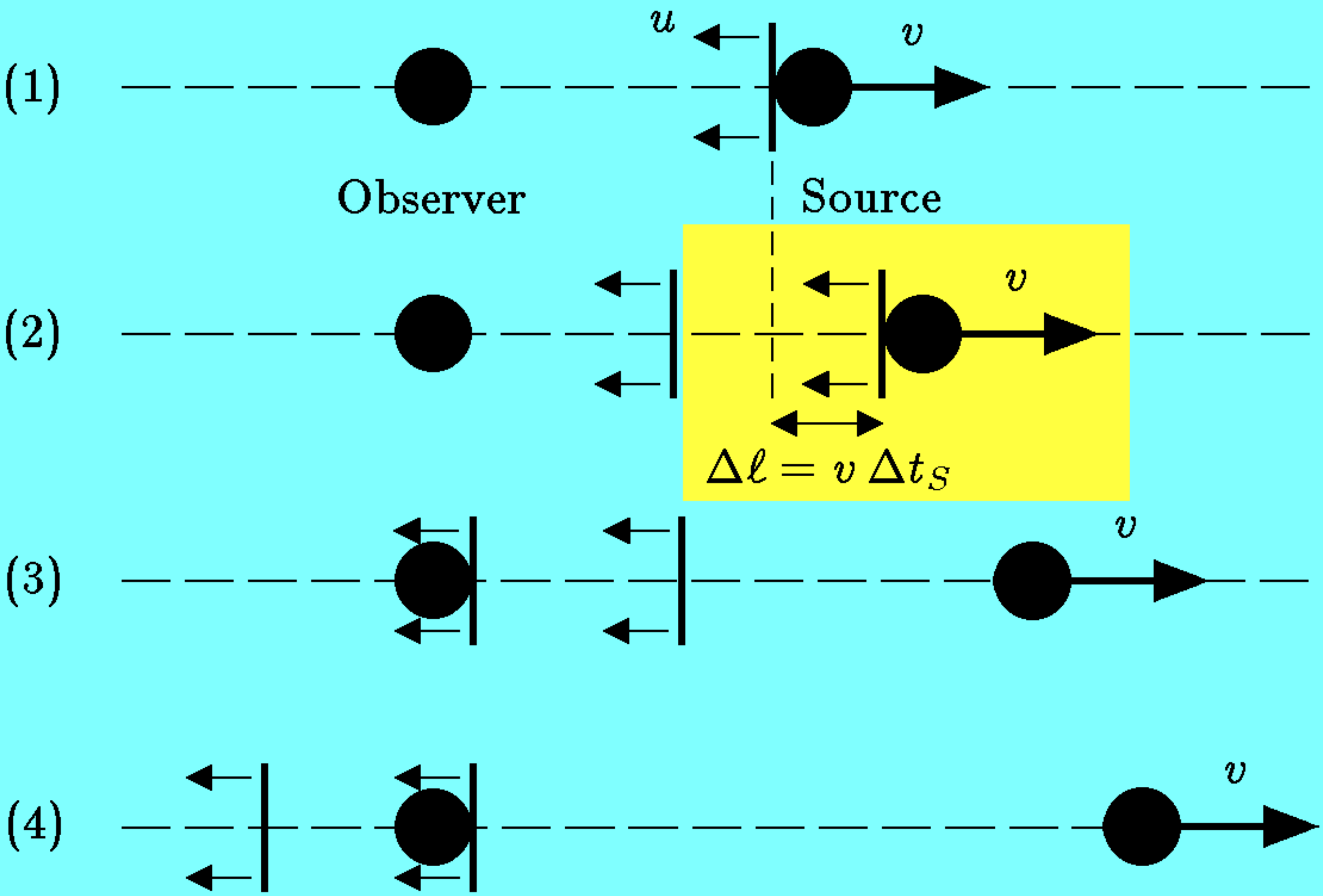

(1)
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$\Delta\ell = v\,\Delta t_S$
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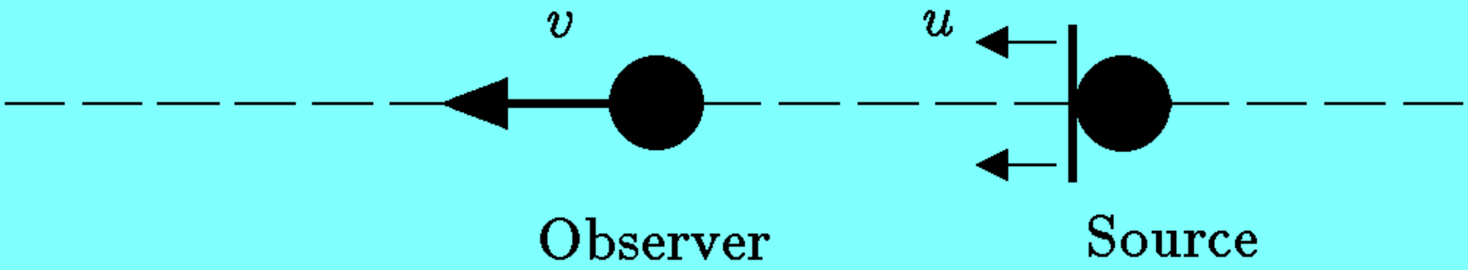
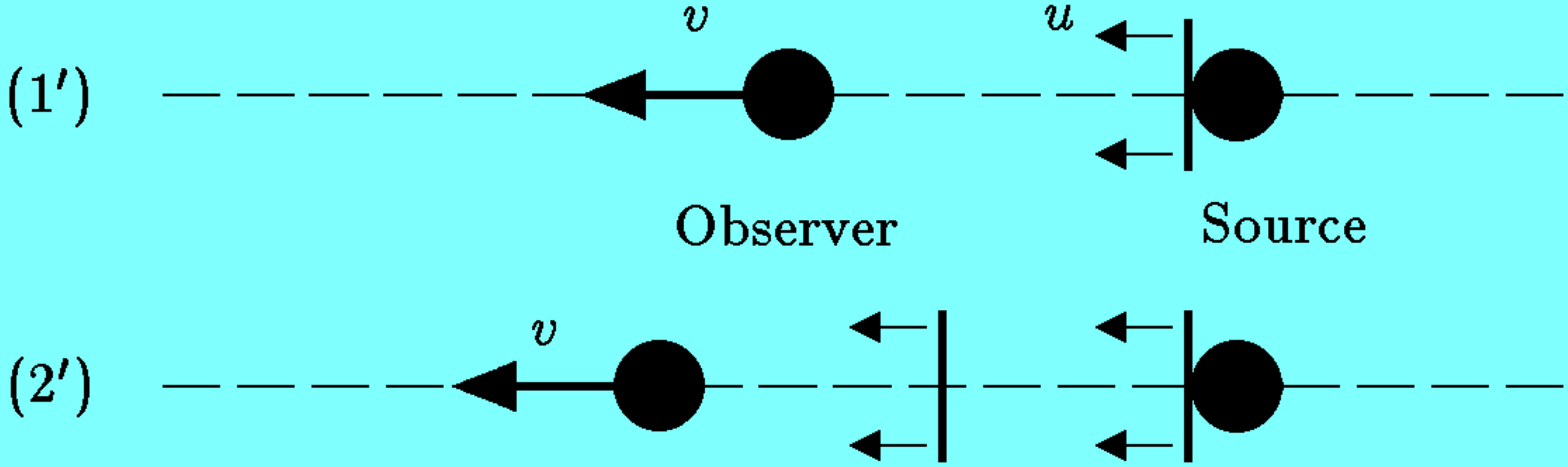
(1′)





(1′)
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Observer
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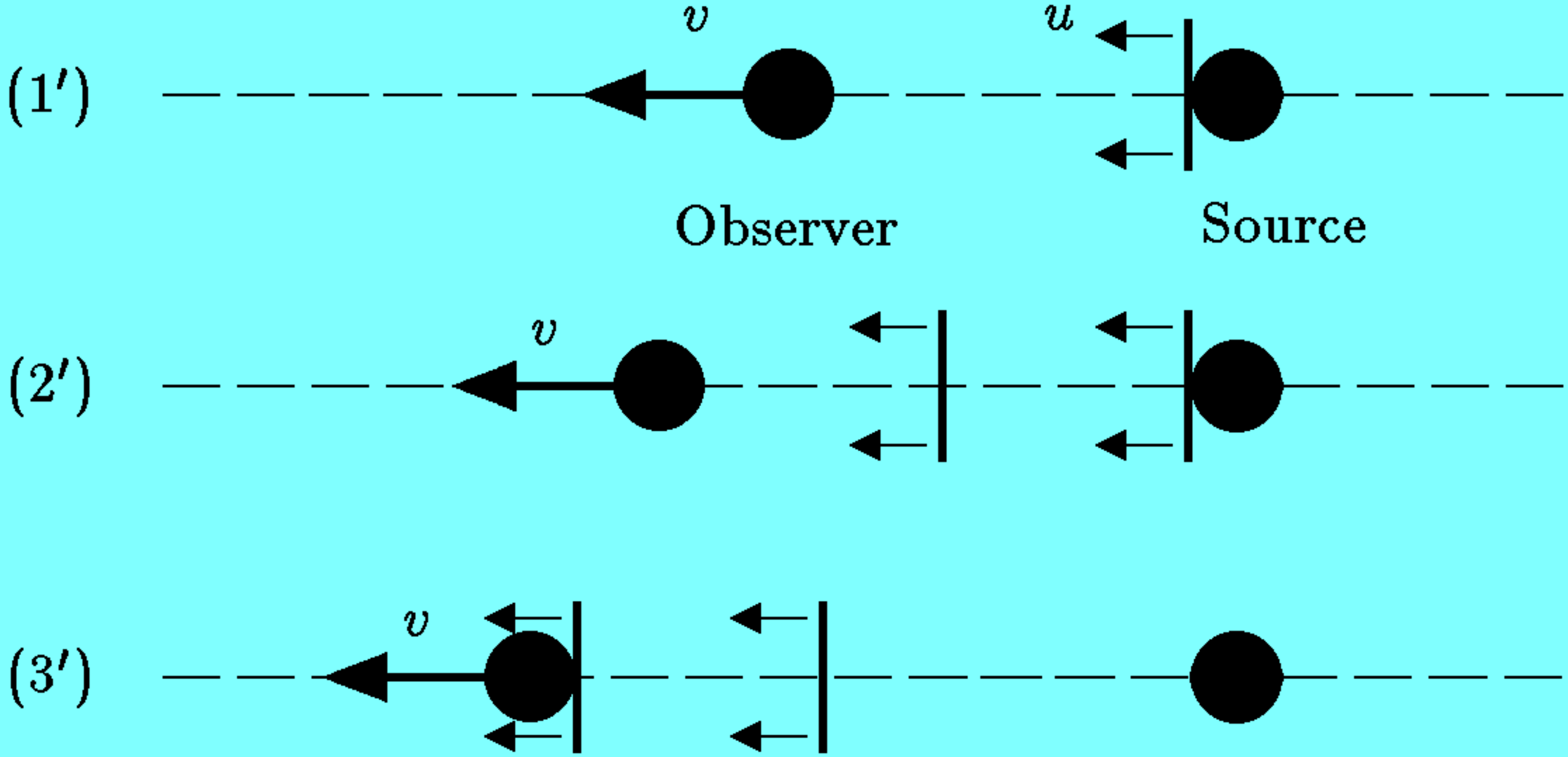
(2′)
v


(1′)
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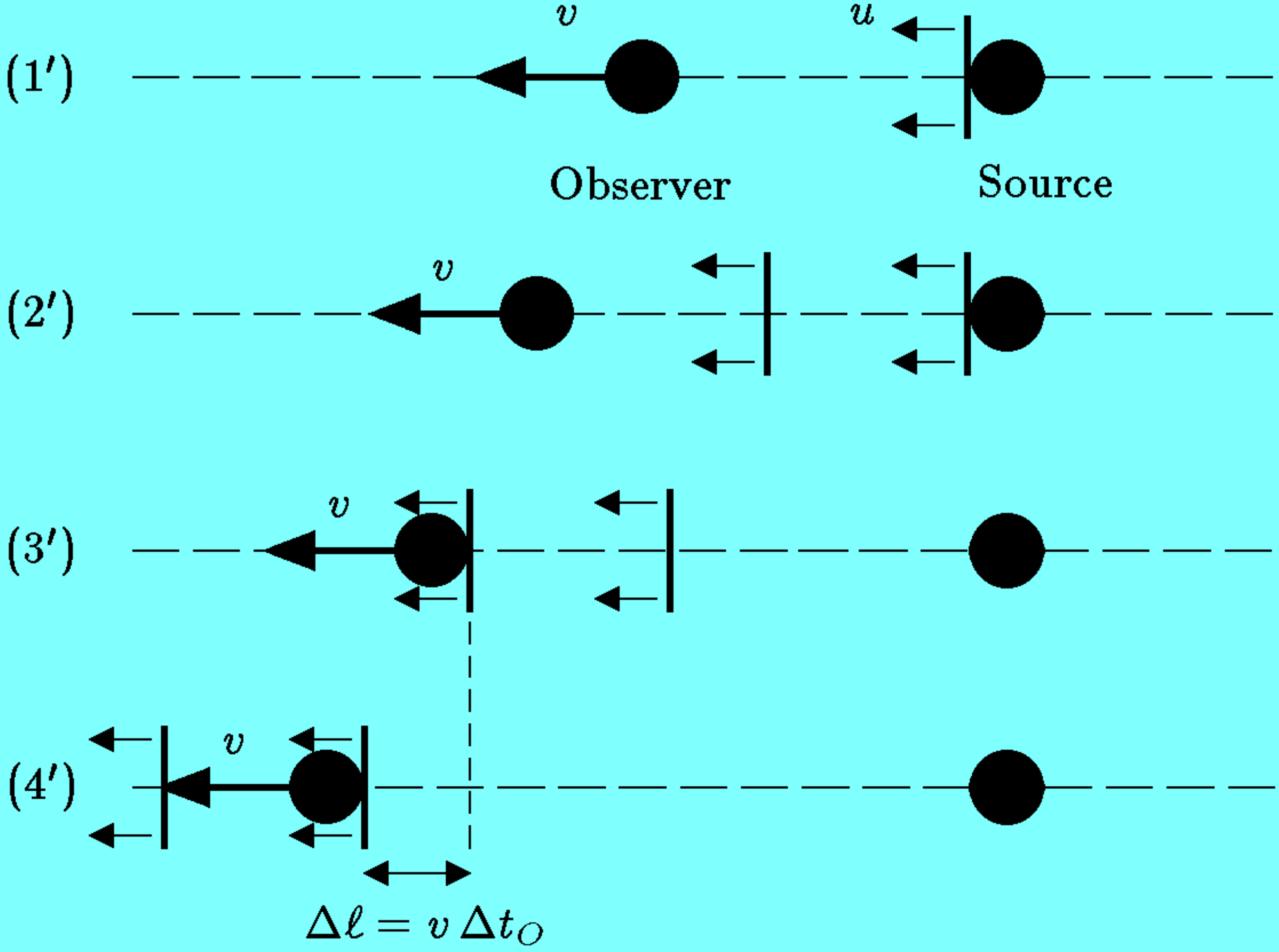
(1′)
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Observer
Source
(2′)
v
(3′)
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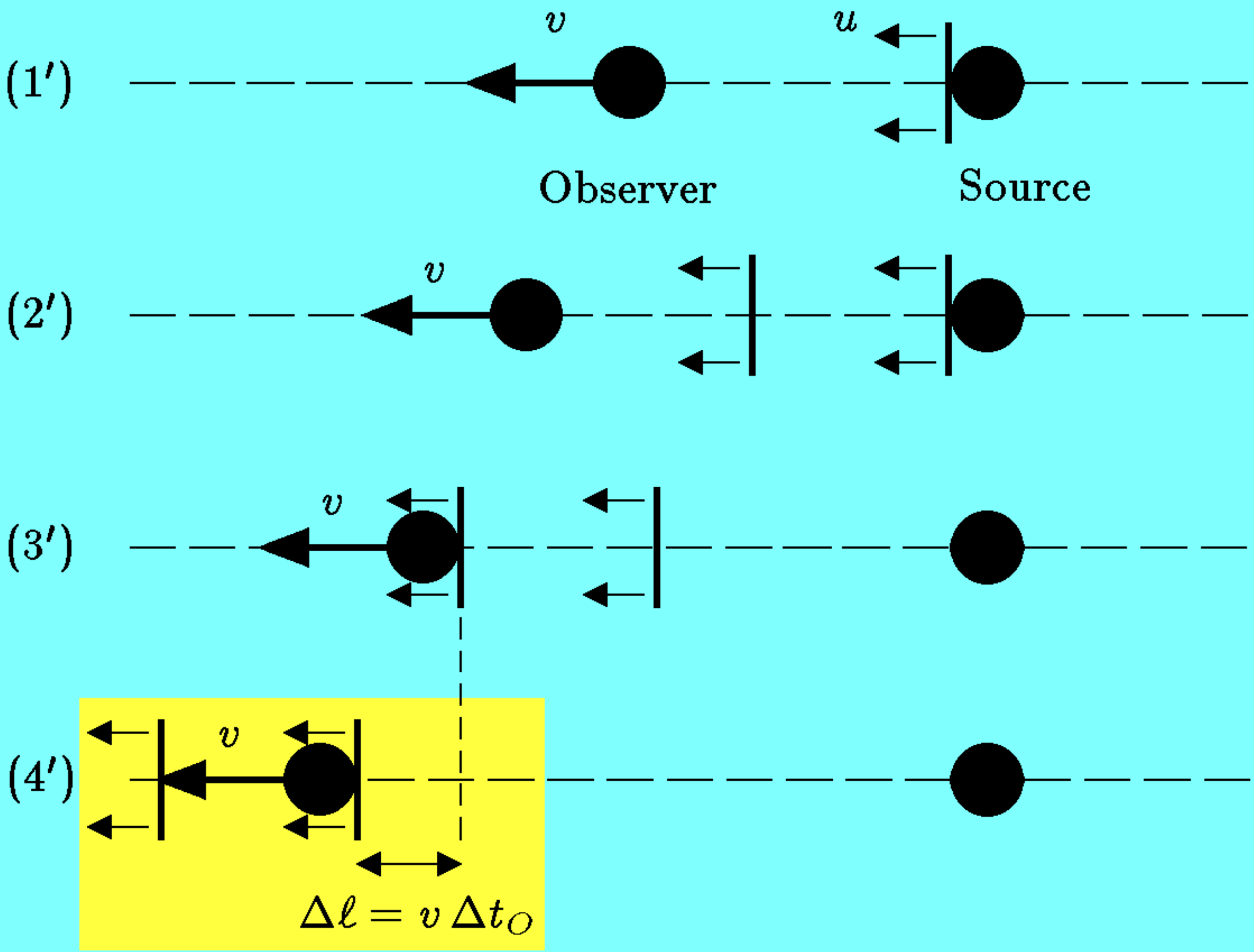
(4′)
v
$\Delta\ell = v\,\Delta t_O$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Observer
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(2′)
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(3′)
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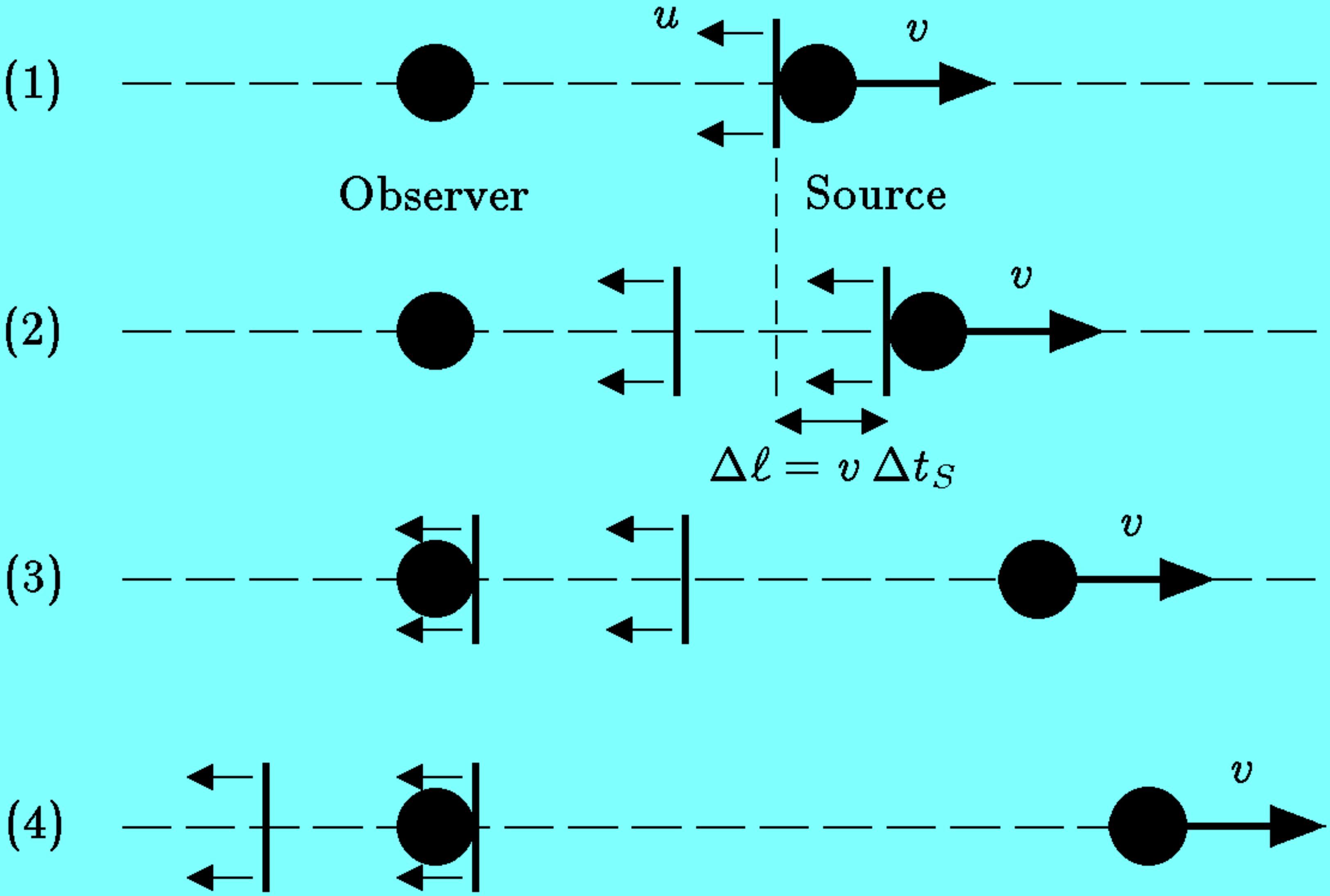
Δℓ = v Δt_O

(1) TIME DILATION: Any clock which is moving at speed v relative to a given reference frame will "appear" (to an observer using that reference frame) to run slower than normal by a factor denoted by the Greek letter γ (gamma), and given by

$$\gamma \equiv \frac{1}{\sqrt{1-\beta^2}} \ , \qquad \beta \equiv v/c \ . \tag{1.10}$$


(1)
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Observer
Source
(2)
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$\Delta\ell = v\,\Delta t_S$
(3)
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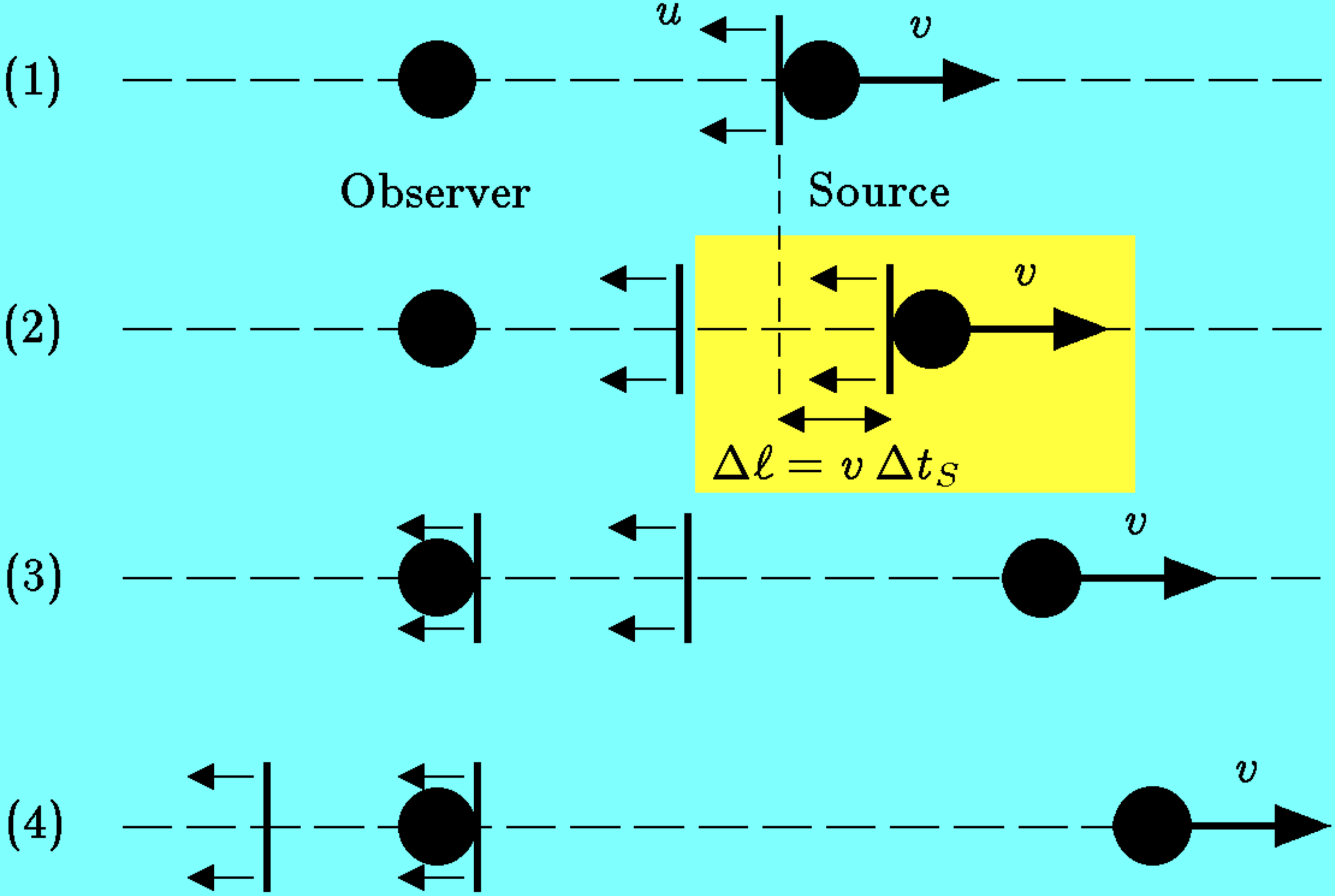

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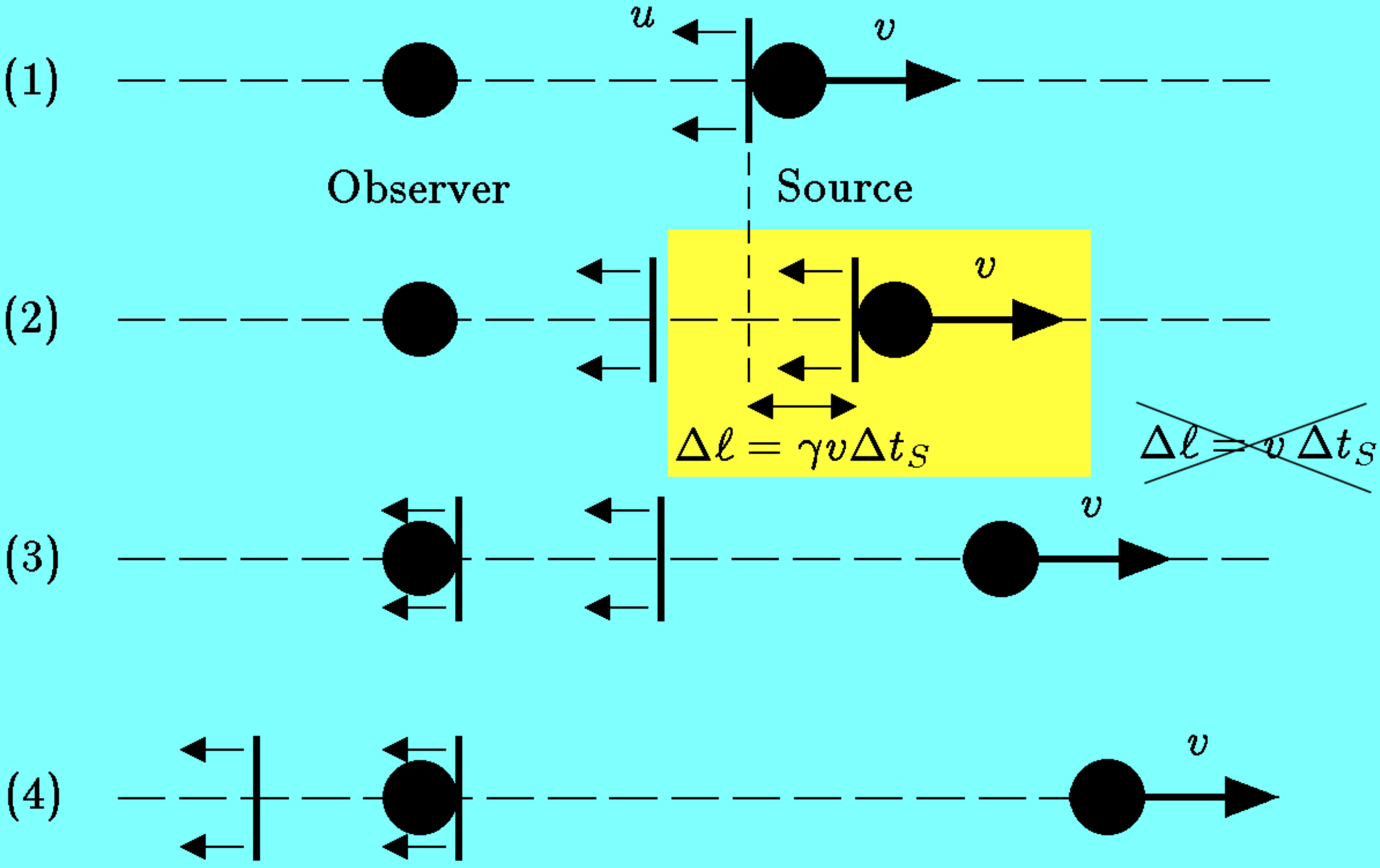
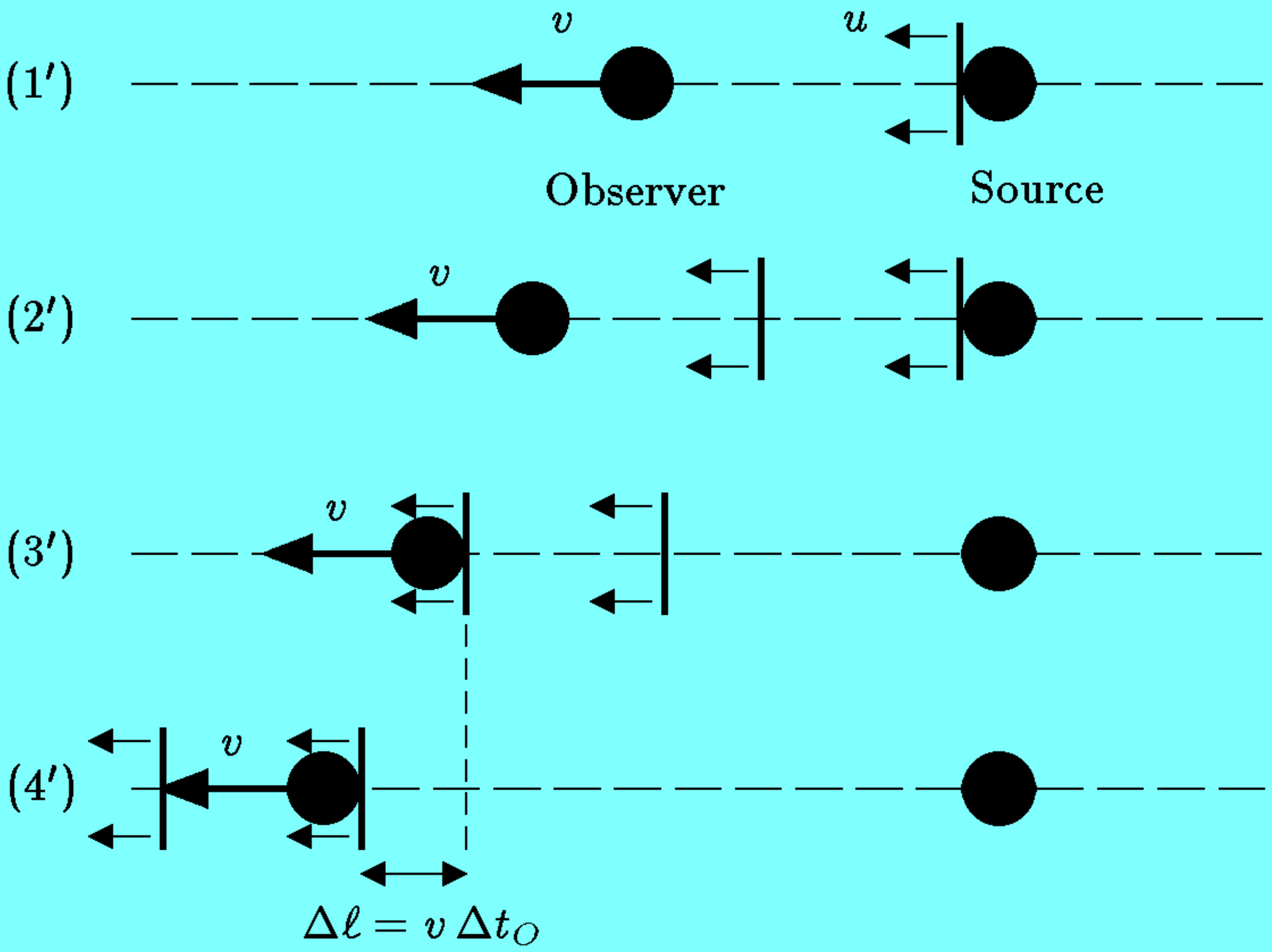
Observer
Source
(2)
v
$\Delta\ell = v\,\Delta t_S$
(3)
v
(4)
v


(1)
u
v
Observer
Source
(2)
v
$\Delta\ell = \gamma v \Delta t_S$
$\cancel{\Delta\ell = v\,\Delta t_S}$
(3)
v
(4)
v



(1′)
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Observer
Source
(2′)
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(3′)
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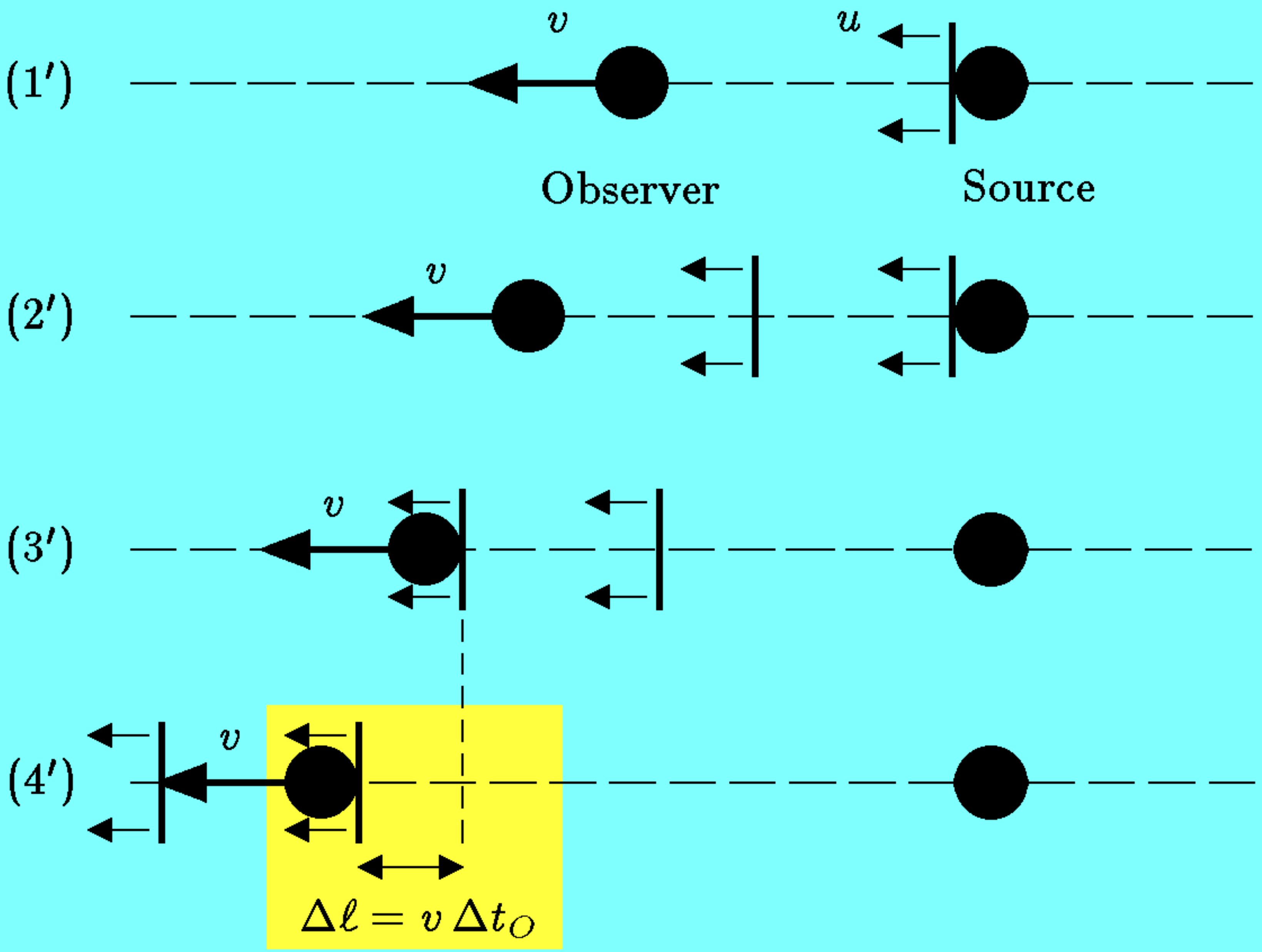
(4′)
v
Δℓ = v Δt_O



(1′)
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(2′)
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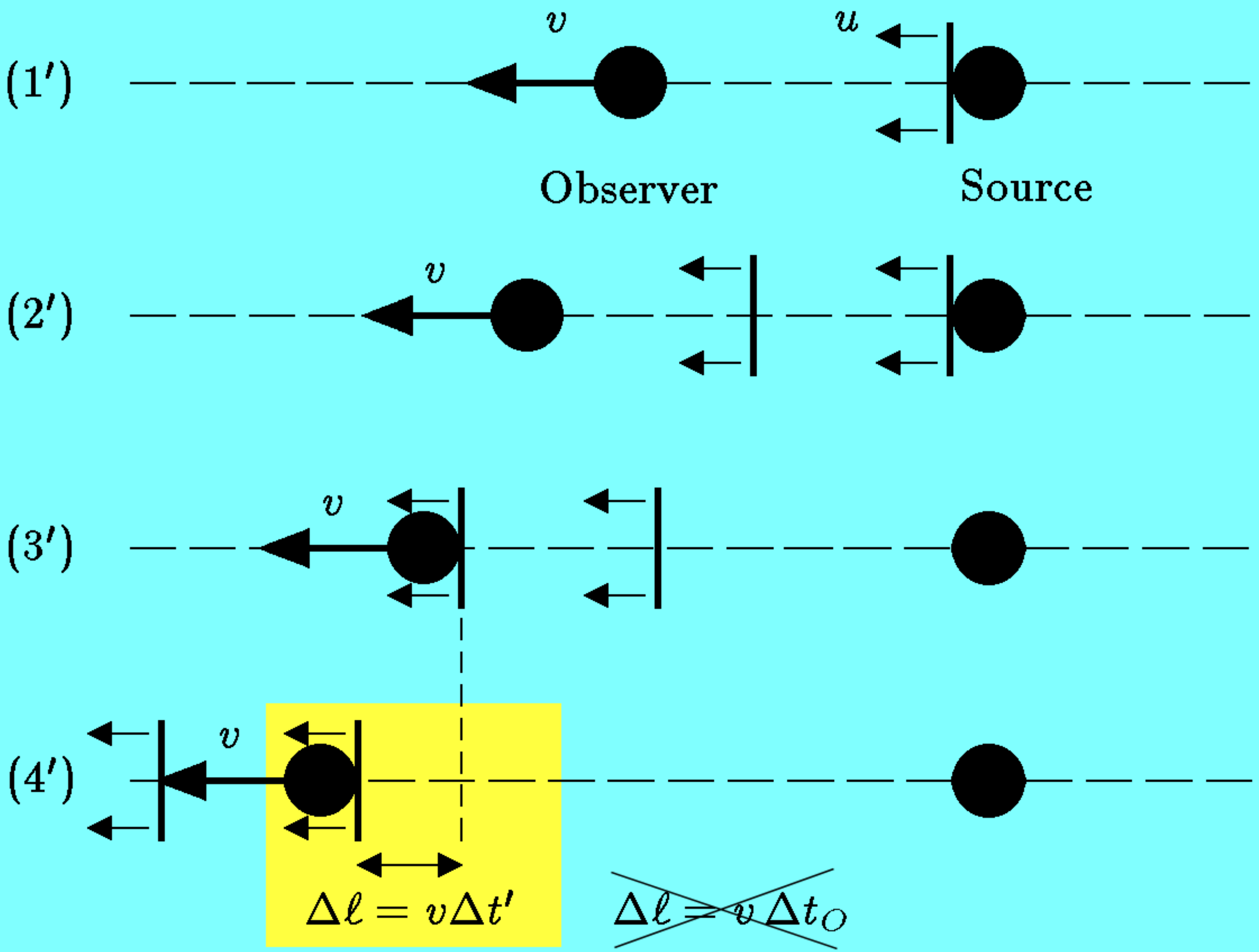
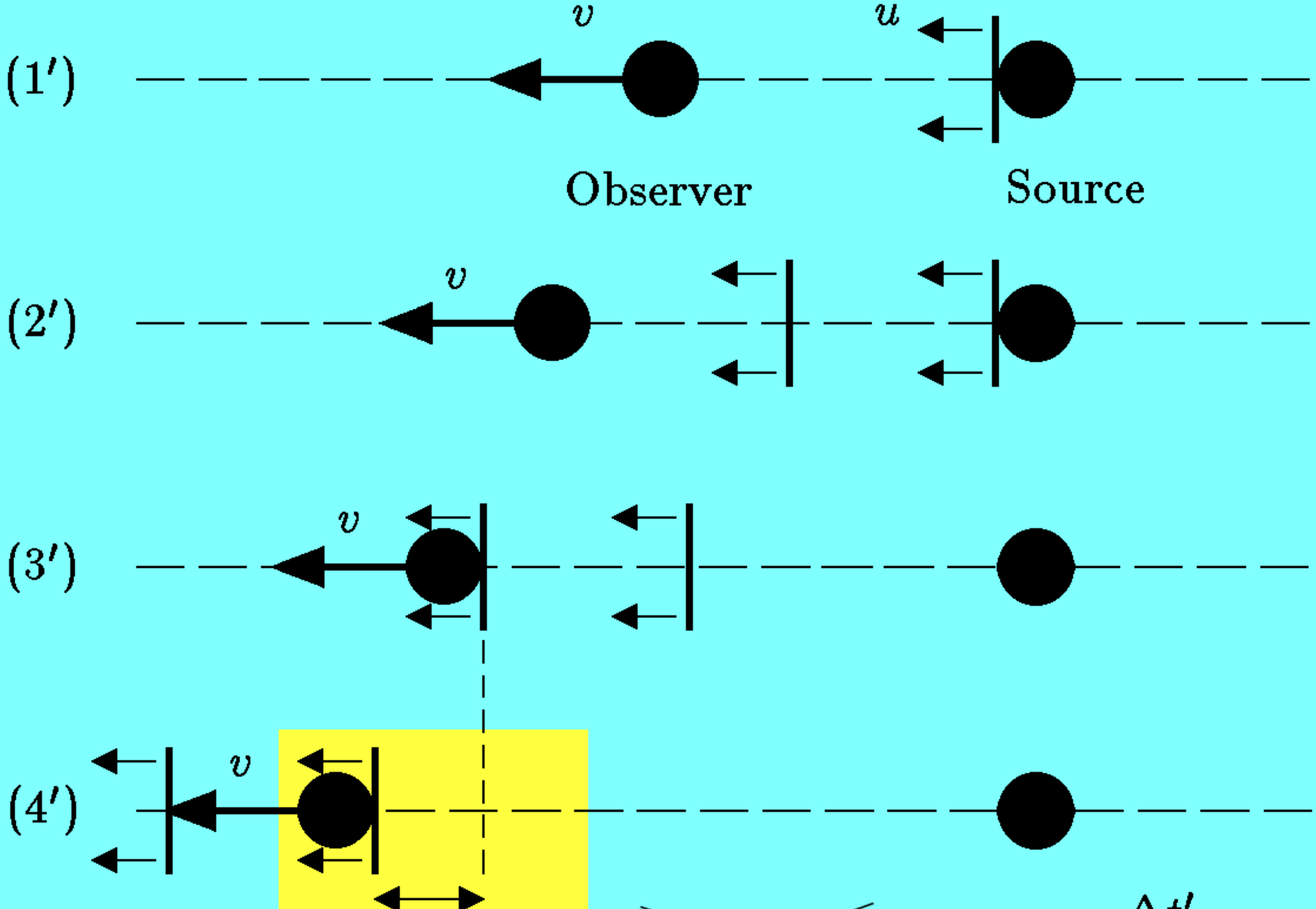
$\Delta\ell = v\,\Delta t_O$



$\Delta t'$ = time between reception of two pulses in frame of the slide.



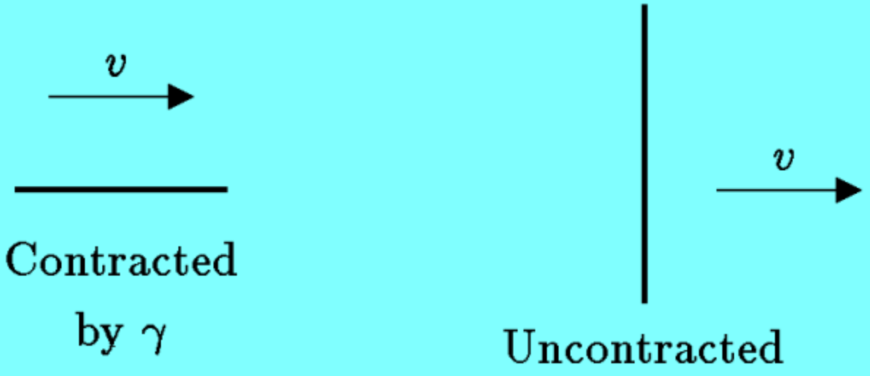
$\boxed{\Delta\ell = v\Delta t'}$ $\quad \cancel{\Delta\ell = v\Delta t_O} \quad \Delta t_O = \dfrac{\Delta t'}{\gamma}$

$\Delta t'$ = time between reception of two pulses in frame of the slide.

(1) TIME DILATION: Any clock which is moving at speed v relative to a given reference frame will "appear" (to an observer using that reference frame) to run slower than normal by a factor denoted by the Greek letter γ (gamma), and given by

$$\gamma \equiv \frac{1}{\sqrt{1-\beta^2}} \ , \qquad \beta \equiv v/c \ . \tag{1.10}$$

(2) LORENTZ-FITZGERALD CONTRACTION: Any rod which is moving at a speed v along its length relative to a given reference frame will "appear" (to an observer using that reference frame) to be shorter than its normal length by the same factor γ. A rod which is moving perpendicular to its length does not undergo a change in apparent length.



(3) RELATIVITY OF SIMULTANEITY: Suppose a rod which has rest length ℓ_0 is equipped with a clock at each end. The clocks can be synchronized in the rest frame of the system by using light pulses. (That is, a light pulse can be sent out from the center, and the clocks at both ends can be started when they receive the pulses.) If the system moves at speed v along its length, then the trailing clock will "appear" to read a time which is later than the leading clock by an amount $\beta\ell_0/c$. If, on the other hand, the system moves perpendicular to its length, then the synchronization of the clocks is not disturbed.