Imperial College London

Relativity – Lecture 3

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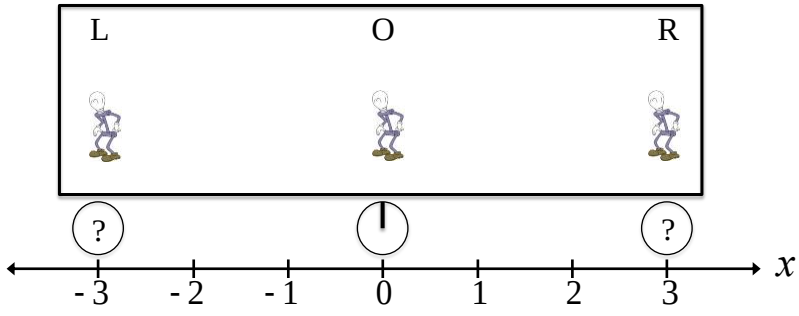
Key points of Lecture 2

- An inertial frame is a frame in which the law of inertia holds.
- Each reference frame contains an infinite number of observers with synchronised clocks who know their position.
- Events happen at a particular position AND at a particular time.
- The fact that observers in all inertial frames measure the same speed of light, *c,* leads to counterintuitive effects.

Synchronised clocks

Oscar sits at the origin of reference frame *S* ($x = 0$).
Meter sticks establish distances in *S*.
Local observers at $x = -3\ \text{m}$ (Lucy) & $x = +3\ \text{m}$ (Ricky).
Procedure to synchronize all clocks in *S* ?



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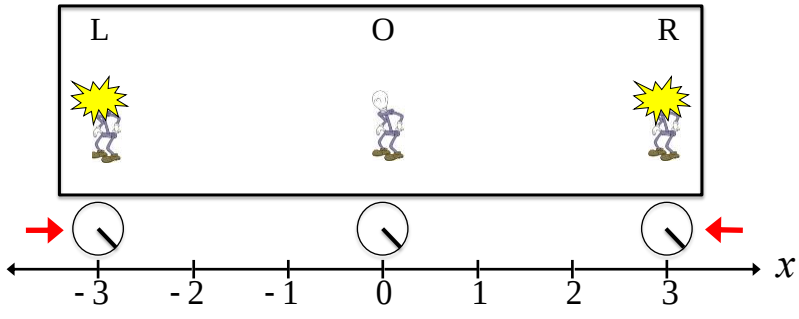
Procedure to synchronize all clocks in frame *S*

Oscar emits a light flash at $t = 0$.
Light spreads outwards in a spherical wavefront.
At $\Delta t = (+3\ \text{m})/c$ the wavefront reaches Lucy and Ricky.



Lucy & Ricky know to set their clocks to $t = (0 + 3\ \text{m})/c$!

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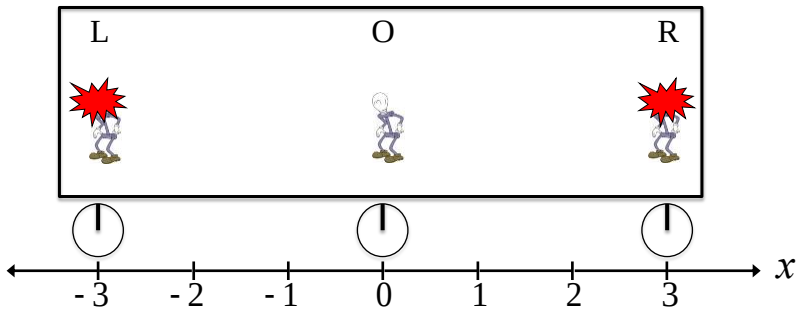
Procedure to synchronize all clocks in frame *S*

Now, all three clocks run in synch with each other!

To check, Lucy & Ricky both emit light flashes at $t = 0$

Oscar receives both light flashes at $t = (0 + 3\ \mathrm{m})/c$



Oscar concludes both flashes were sent simultaneously.

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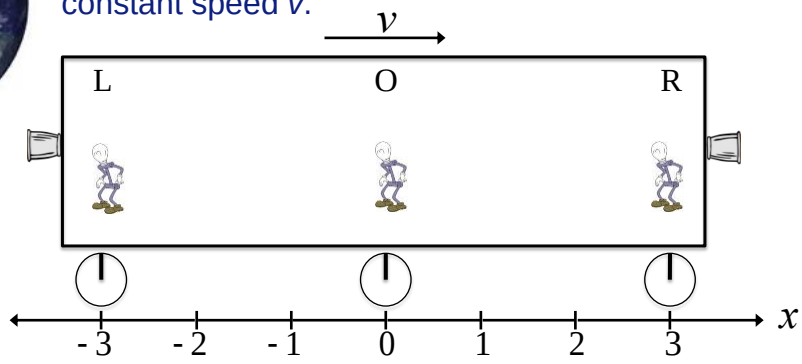
Changing to a different inertial frame

It's revealed that Lucy, Oscar and Ricky are actually in a spaceship moving away from the Earth at a constant speed *v*.



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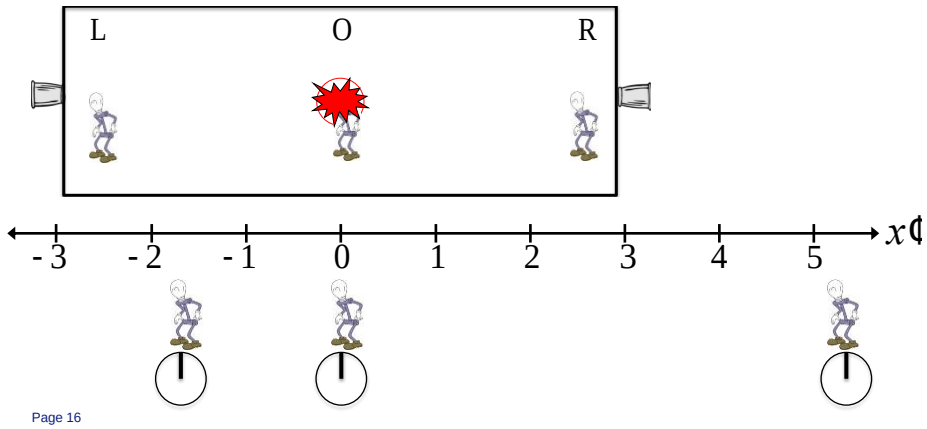
What does this procedure look like in a different frame S'?
Frame S moves to the right with speed *v* relative to frame S'.

- Oscar emits a light flash at $t = t' = 0$ & $x = x' = 0$.



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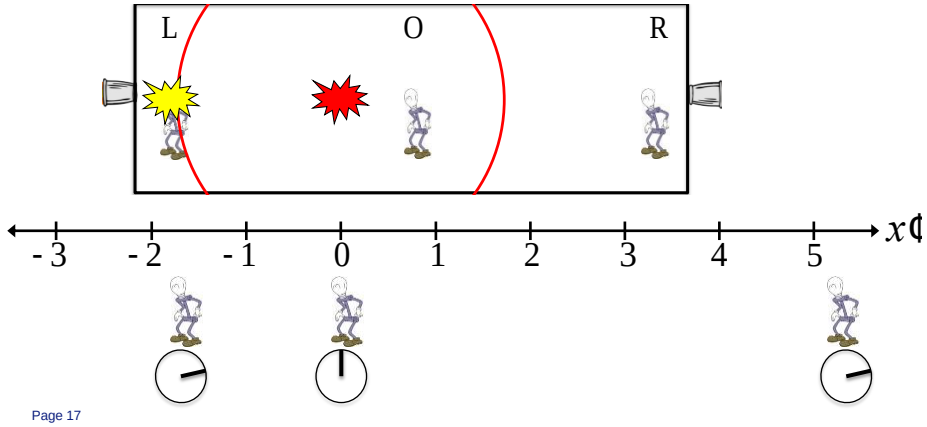
What does this procedure look like in a different frame S'?
Frame S moves to the right with speed *v* relative to frame S'.

- Oscar emits a light flash at $t = t' = 0$ & $x = x' = 0$.
- Light spreads outwards in a spherical wavefront.
- The wavefront reaches Lucy.



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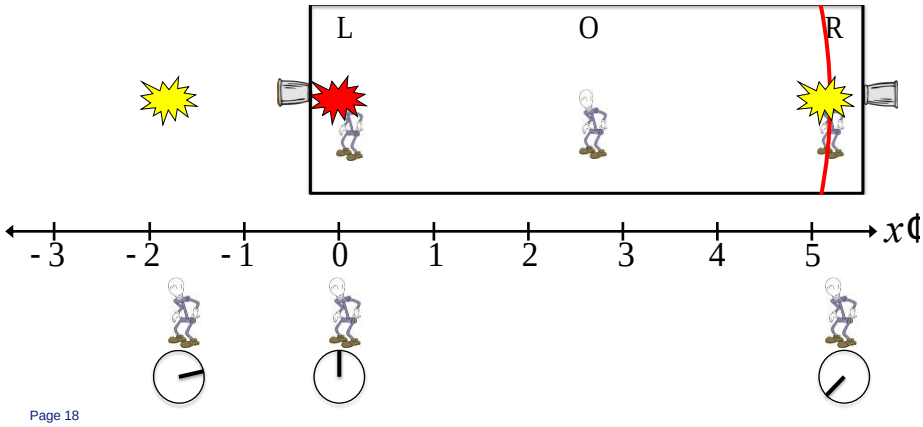
What does this procedure look like in a different frame S'?
Frame S moves to the right with speed *v* relative to Frame S'.

- Oscar emits a light flash at $t = t' = 0$ & $x = x' = 0$.
- Light spreads outwards in a spherical wavefront.
- The wavefront reaches Lucy.
- At some later time the wavefront reaches Ricky.



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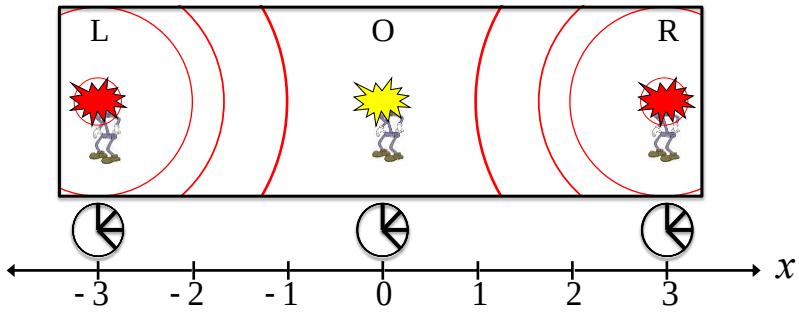
Remember this situation? Lucy & Ricky both emit light flashes at $t = 0$ in frame S.

Oscar receives both light flashes at $t = (0 + 3\ \mathrm{m})/c$.



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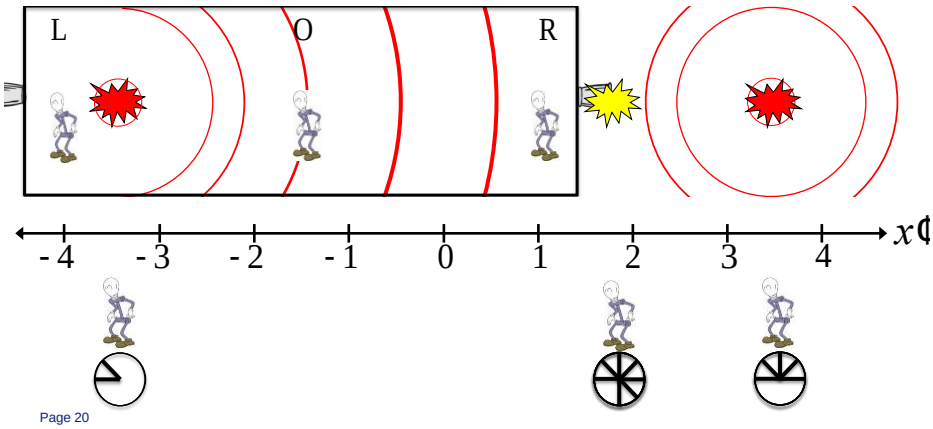

Important Point

If two events occur at the same point in space *and also* at the same point in time in frame S:

Event 1: Light from Lucy reaches Oscar – $ct = +3$ & $x = 0$
Event 2: Light from Ricky reaches Oscar – $ct = +3$ & $x = 0$

…then they occur at the same point in spacetime in every inertial reference frame – only the coordinates are different.

A stationary light clock

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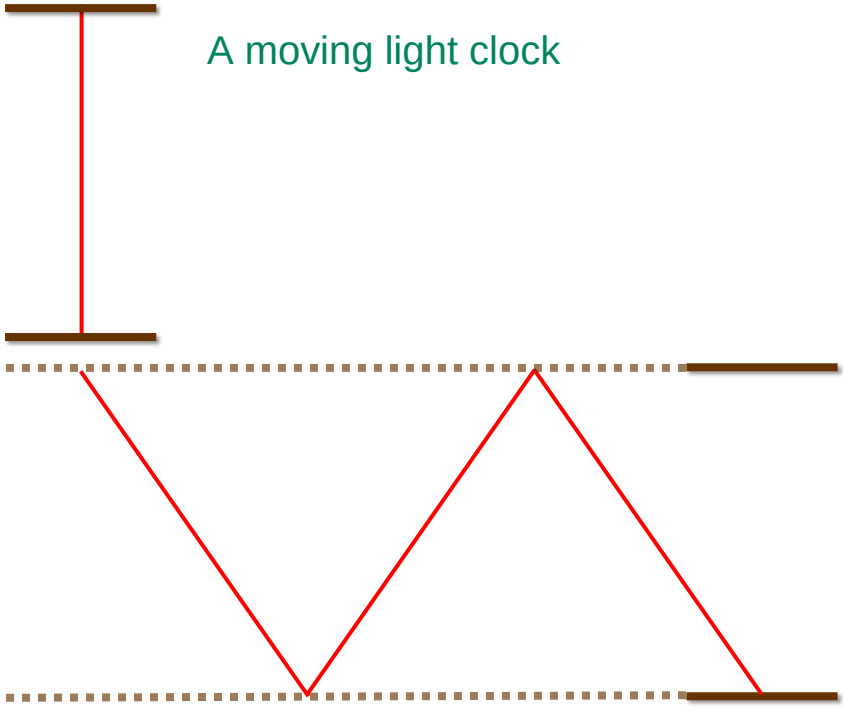
A moving light clock



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Time dilation

Proper time

A stationary observer sees a moving clock run slow.

Stationary clocks measure the shortest time interval between two events.

Measuring the length of a rod

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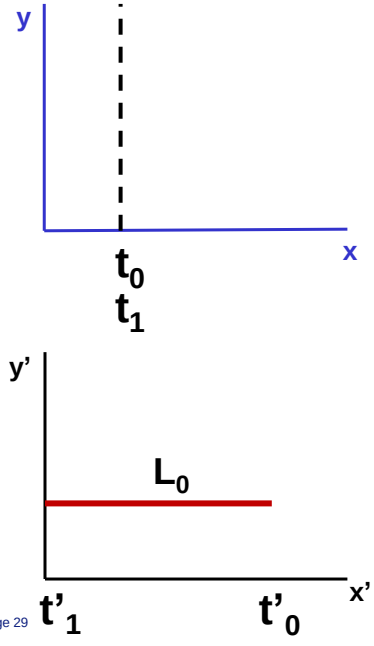

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Summary of concepts

- Events that are simultaneous in one inertial frame and spatially separated, are non-simultaneous in another inertial frame.
- Time dilation: moving clocks run slow.
- Proper time: the time interval measured between 2 events by a stationary clock.
- Length contraction: moving objects are short.