3D Time:
From Transportation to Physics
Part 7: Relativity

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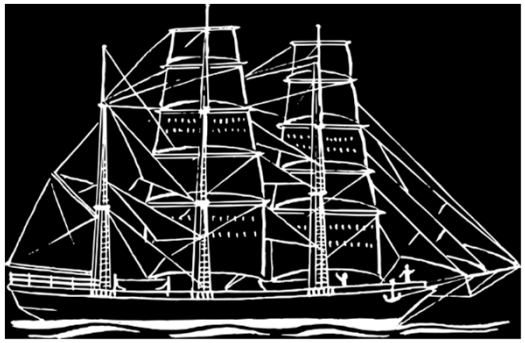
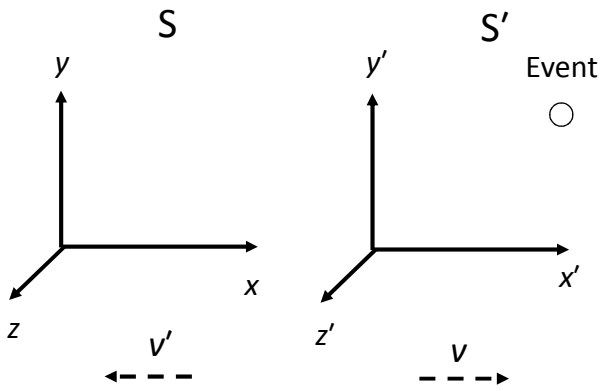
Galileo's relativity

- Large ship at constant velocity
  - rest and moving
  - below deck
- Experiments
  - throw something to a friend
  - put legs together and jump up
  - motion is the same in all directions
- So constant velocity is relative



Transformations in *space*

- Frames of reference, S & S′
  - coincide at time $t=t'=0$
  - parallel to x-axis
- Frame S
  - view S′ velocity v'
- Frame S′
  - view S velocity v
- Both observe an event
  - what coordinates?



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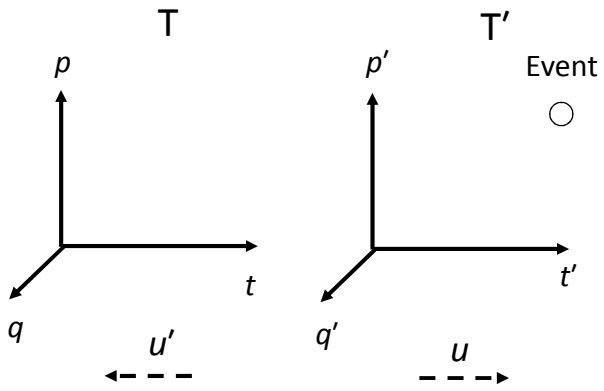
Transformations in *time*

- Timeframes, T & T′
  - coincide at radius $r=r'=0$
  - parallel to t-axis
- Timeframe T
  - view T′ legerity u'
- Timeframe T′
  - view T legerity u
- Both observe an event
  - what coordinates?



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Galilean transformations

- Galilei in 3D *space*
- Frame S
  - $x' = x - vt$
  - $t' = t$
- Frame S′
  - $x = x' + vt'$
  - $t = t'$
- Space in relative
  - time is absolute

- Galilei in 3D *time*
- Timeframe T
  - $t' = t - ux$
  - $x' = x$
- Timeframe T′
  - $t = t' + ux'$
  - $x = x'$
- Time is relative
  - space is absolute

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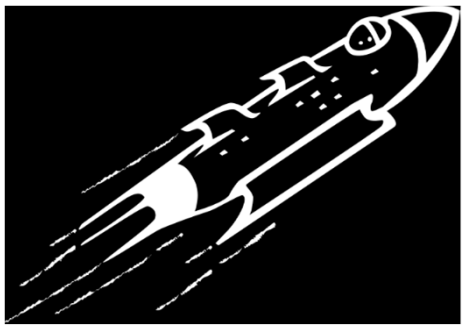
Lorentz transformation in 3D *space*

- Lorentz and Einstein
  - absolute speed of light, *c*
  - constant from every frame
  - the maximum speed
- Spherical wavefront of light
  - distance *r* from S and *r*′ from S′
  - $r = ct$
  - $r' = ct'$



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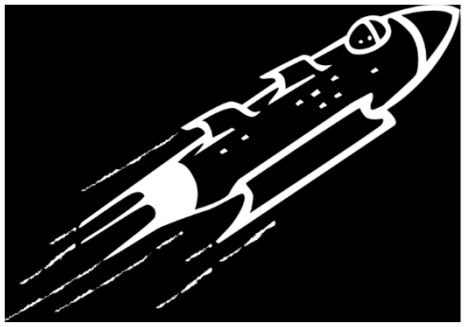
Lorentz transformation in 3D *space*

- Frame S
  - $x' = \gamma (x - vt)$
- Frame S′
  - $x = \gamma (x' + vt')$
- Lorentz transformation
  - $\gamma^2 = 1 / (1 - v^2/c^2)$
  - $t' = \gamma (t - vx/c^2)$
- Time dilation and length contraction



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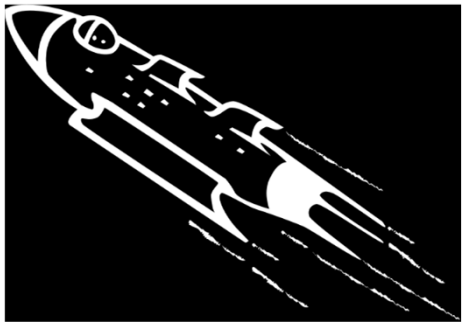
Lorentz transformation in 3D *time*

- Lorentz and Einstein
  - absolute *pace* of light, $ç = 1/c$
  - constant from every timeframe
  - the minimum pace
- Spherical wavefront of light
  - duration t from T and t' from T′
  - $t = çr$
  - $t' = çr'$



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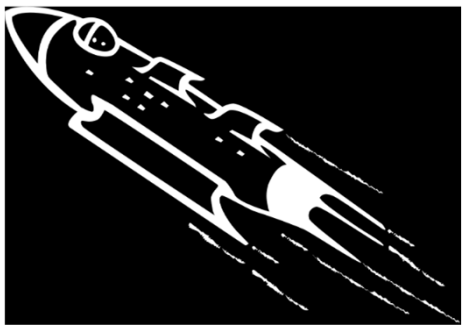
Lorentz transformation in 3D *time*

- Timeframe T: *length*
  - $x' = \gamma\,(x - t/u)$
- Timeframe T′
  - $x = \gamma\,(x' + t'/u)$
- Lorentz in 3D time
  - $\gamma^2 = 1 / (1 - ç^2/u^2) = 1 / (1 - v^2/c^2)$
  - $t' = \gamma\,(t - ç^2 x/\mathrm{v}) = \gamma\,(t - vx/c^2)$
- Same time dilation and length contraction



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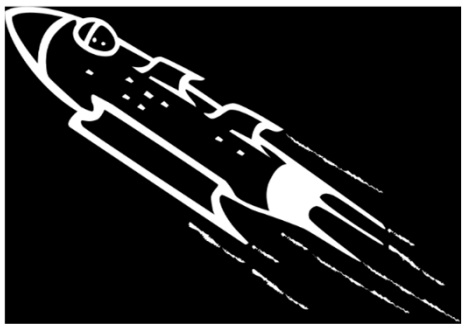
Lorentz transformation in 3D *time*

- Timeframe T: *duration*
  - $t' = \lambda\,(t - ux)$
- Timeframe T′
  - $t = \lambda\,(t' + ux')$
- Lorentz in 3D time
  - $\lambda^2 = 1 / (1 - u^2/ç^2) = 1 / (1 - c^2/v^2)$
  - $x' = \lambda\,(x - ut/ç^2) = \lambda\,(x - c^2 t/v)$
- Speeds greater than light



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One-way speed of light

- Measure by reflecting light
  - two one-way speeds of light
  - harmonic mean equals *c*
- Synchrony conventions
  - define simultaneity for frames
- Conventions available
  - one-way speed always equals *c*
  - incoming or outgoing speed is ∞
  - other way speed is *c*/2

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Qualitative difference?

- Convention in 3D *space*
  - instantaneous *incoming* light
- Lorentz transformation
  - $c \rightarrow \infty$
  - $\gamma = 1$
  - $t' = t$
- = Galilean transformation
- Space in relative
  - time is absolute
- Instant observation

- Convention in 3D *time*
  - instantaneous *outgoing* light
- Lorentz transformation
  - $c \rightarrow \infty$
  - $\lambda = 1$
  - $x' = x$
- like Galilean transformation
- Time is relative
  - space is absolute
- Instant transmission

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Equivalence principles

- Elevator example
  - detect acceleration down
  - is it gravity pulling things down or an
  - acceleration pushing the elevator up?
- Cannot tell the difference
- Same for expedience
  - detect expedience up
  - it is levity pulling the elevator up or
  - an expedience pushing things down?

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In conclusion

- Galilean transformation in 3D *space*
  - instant observation
- Galilean transformation in 3D *time*
  - instant transmission
- Lorentz transformation
  - in 3D space and 3D time
- Equivalence principles
- 3D time does relativity
- Next is *Part 8: 6D Spacetime*

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