# Test 1 Mechanics & Relativity

Friday September 15, 2017, 9:00-11:00, Aletta Jacobshal

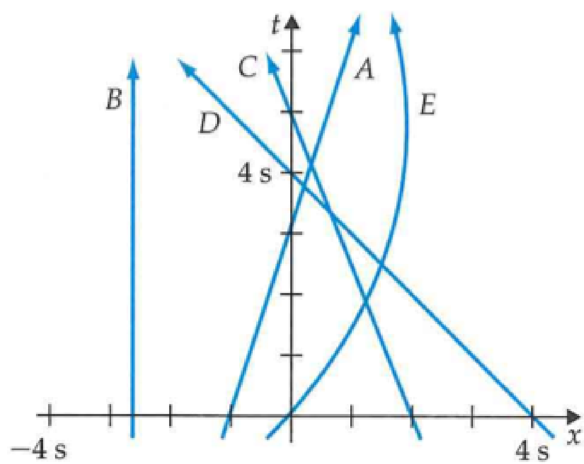
*Before you start, read the following:*

- There are 4 problems for a total of 40 points.
- *Write your name and student number on each sheet of paper.*
- Make clear arguments and derivations and use correct notation.
- Support your arguments by clear drawings where appropriate.
- Write in a readable manner, illegible handwriting will not be graded.
- *Good luck!*

**Problem 1** (*30 minutes max.; 10 points in total*)

*1 pnt* (a) Who was the first to formulate the principle of relativity?

*1 pnt* (b) What, in SR units, is approximately the distance from Earth to Moon?




*3 pnts* (c) For each of the worldlines in the Figure, describe what the objects are doing and give the values for their velocities when possible.

Are the following statements true or false?

*1 pnt* (d) There is no meaningful distinction between an inertial reference frame at rest and one moving at a constant velocity.

*1 pnt* (e) An object has the same momentum in every inertial reference frame.

*1 pnt* (f) In Newtonian mechanics, coordinate time is frame-independent.

*1 pnt* (g) The proper time $\Delta\tau$ between two events depends on the worldline of the clock.

*1 pnt* (h) The coordinate time $\Delta t$ between two events can never be larger than their spacetime interval $\Delta s$.

**Problem 2** (*30 minutes max.; 10 points in total*)

Consider a spaceship that leaves Earth at event $A$ and travels in the $+x$ direction. It accelerates at a constant rate from rest at time $t = 0$ to a final speed of 4/5 at time $t = 1$ hour. It remains at that speed thereafter. Just as the spaceship reaches its final speed, it emits a laser signal back toward Earth, this is event $B$. The signal reaches Earth at event $C$.

*3 pnts* (a) Show that the spacetime coordinates of event $B$ are $(t, x) = (1, 0.4)$ in hours.

*7 pnts* (b) Draw a quantitatively accurate spacetime diagram of this situation (as observed in a frame attached to Earth, with Earth at $x = 0$) that shows the worldlines of Earth, the spaceship, the returning laser signal, and events $A$, $B$, and $C$. Label the axes in hours.

**Problem 3** (*30 minutes max.; 10 points in total*)

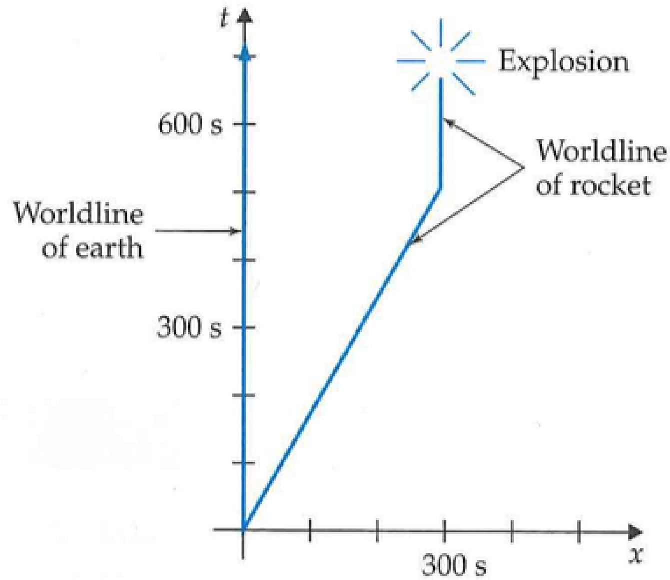
A muon is created by cosmic rays in Earth's atmosphere at an altitude of 60 km. Imagine that, after its creation, the muon travels downward at a speed of 0.998, as measured by an observer on the ground. After the muon's "internal clock" registers 2.0 $\mu$s, this particular muon decays.

*4 pnts* (a) Suppose that special relativity is *not* true and time is universal and absolute. Then clocks on the ground would measure the same time between the muon's creation and decay as the muon's clock does. In this case, about how far would this muon have traveled before it decays?

*6 pnts* (b) Special relativity *is* in fact true. How far does this muon actually travel (in the inertial reference frame of the observer on the ground) before it decays?

**Problem 4** (*30 minutes max.; 10 points in total*)

The spacetime diagram shows the worldlines of a rocket as it leaves Earth (event $A$), travels for some time, comes to rest in deep space (event $B$), and then explodes (event $C$).




*4 pnts* (a) What are the spacetime coordinates of the events $A$, $B$, and $C$? What is the rocket's constant speed relative to Earth before it comes to rest?

*2 pnts* (b) A light signal from Earth reaches the rocket just as it explodes. Copy the diagram on your paper and indicate exactly where and when this light signal was emitted.

*4 pnts* (c) How much time elapses between the departure of the rocket and its explosion, as measured by its flight recorder? What is the spacetime interval between these two events?