Review Questions
(week of 18 May 2020)

1. What is a worldline? How is the slope of the tangent line to a wordline related to the velocity of a particle.
2. Write down the Lorentz transformation for x, y, z and t using the matrix notation.
3. On a ct–x Minkowski diagram sketch a fragment of the worldline of a particle that (a) moves with constant speed $v = c/3$ in the positive x–axis direction, (b) moves in the positive x–axis direction, with acceleration in the negative x–axis direction, (b) rests at the origin.
4. How do we define the space–time interval? What do we mean by saying that it is an invariant of the Lorentz transformation. How can you prove that it is invariant? (give the idea only, no detailed calculations needed)
5. Argue that for two events separated by a time-like space-time interval it is impossible to find a FoR where they are simultaneous.
6. Argue that for two events separated by a space-like space-time interval it is impossible to find a FoR where they happen at the same place.
7. Two events are separated by a time-like space-time interval. Is it possible that there is a cause–effect relation between them?
8. Two events are separated by a space-like space-time interval. Is it possible that there is a cause–effect relation between them?
9. Two events are related to each other by a cause–effect relationship. Can you find a FoR where these two events happen at the same instant of time? At the same place?
10. On a Minkowski diagram mark two events that are separated by a (a) space-like, (b) time-like space-time interval.
11. Why the equation of motion in the form $\mathbf{F} = m\mathbf{a}$, with mass m that is invariant, cannot be correct in relativistic mechanics?
12. In relativistic mechanics, the momentum of a particle is $\mathbf{p} = m(u^2)\mathbf{u}$. What fundamental principle can be used to find the functional dependence of the particle's mass on its speed u? Write down the explicit form of $m(u^2)$.
13. For a massive particle, the dependence of the particle's mass on its speed implies that $p \to \infty$ as $u \to c$. Explain why photons, that have finite momentum, can still move at the speed of light c.
14. Photons are particles with .... rest mass, moving with speed ....
15. How do we define the rest mass?
16. *True or false*: Mass in the special theory of relativity is a scalar quantity.
17. The equation of motion in the special theory of relativity is $F_i = m_{ij}a_j$, where m_{ij} is the mass tensor. What does this equation imply with regard to the mutual orientation of the force and the acceleration vectors?

18. In relativistic dynamics, the acceleration of a particle acted upon a non-zero net force is always parallel to that force.

19. In the limit $u \ll c$ the mass tensor simplifies to the form m_{ij} = ..., that is, effectively, the mass can be treated as a .... Consequently, the force and the acceleration vectors are ....

20. For one-dimensional motion of a particle with speed u sketch the dependence of the magnitude of the momentum as a function of u/c in the (a) relativistic, (b) non-relativistic mechanics.

21. In relativistic mechanics, the equation of motion of a particle moving along the x–axis can be written in the form $F_x = dp_x/dt$, same as in non-relativistic mechanics, but the momentum must be redefined as $p_x =$ ....

22. For one–dimensional motion, sketch the time dependence of the velocity of a particle acted upon a constant force. Assume that the particle starts from rest.

23. In relativistic mechanics the total energy of a particle $E =$ .... and its kinetic energy $K =$ ....

    Explain all symbols on the r.h.s. of the formulas.

    In the limit $u \ll c$, the kinetic energy of a particle $K =$ .... and its momentum $\mathbf{p} =$ ....

24. Whenever some additional energy of any form is stored in an object, its mass .... by ....

25. What do we mean when we say that there is equivalence between mass and energy? Give an example.

26. What is the binding energy?

27. Compared with the energy needed to ionize a hydrogen atom, the amount of energy needed to break apart an alpha particle is much .... (answer: greater)