Test from special relativity

Instructions:
The time limit for completing the test is **30 minutes**.

The questions are divided into eight groups, with each group containing introductory information that relates to all questions in that group.

There are 4 options to choose from for each question, **only one option is correct**. Circle or underline the answer you think is correct.

There is 1 point for each correctly answered question, **no points are lost for incorrect answers**. The maximum possible score is 24 points.

For questions 13–24, please include the calculation or justification of the answer, otherwise your answer will not be recognized!

Allowed aids: pencil, calculator

Please fill in the following data:
Gender: Female/Male
School: . . . . . .

I. For the transition from one inertial frame of reference to another in relativistic mechanics we use Lorentz transformations of time and coordinates.

1. Choose the correct statement from the following options:
   a) Objects A and B move at speeds close to c. Their relative speed is given by the sum of their individual speeds.
   b) We should replace classical mechanics with relativistic mechanics if bodies move relative to the Earth with a non-zero acceleration.
   c) Classical mechanics applies only in the case of small relative velocities of bodies with respect to c.
   d) In the case of speeds close to c, the kinetic energy is calculated according to the relation $E_k = \frac{1}{2}mv^2$.
2. Which of the following physical quantities is not changing at a very high relative velocity of the reference frames?
   a) Total energy; b) kinetic energy; c) rest energy; d) momentum.

II. A space rocket moves at a speed of 0.5c away from the Sun, then turns and moves at the same speed towards the Sun.

3. At what speed does the light from the Sun hit the rocket as it moves away from it?
   a) 0.5c; b) 0.75c; c) 0.3c; d) c.

4. At what speed does the light from the Sun hit the rocket as it moves towards it?
   a) 0.5c; b) 0.75c; c) 0.3c; d) c.

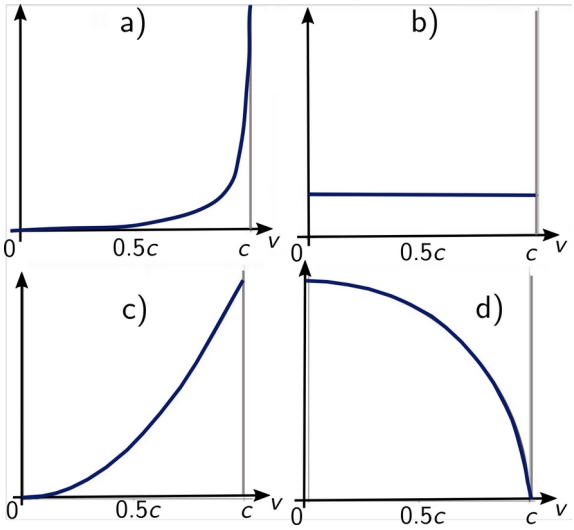
III. Alice flies in a rocket at a speed close to c towards Bob standing on the asteroid.

5. The moment Alice flies past Bob, she sends two flashes of light to him according to her clock in the range of 1 nanosecond. What is the interval between flashes according to Bob?
   a) Less than 1 nanosecond; b) exactly 1 nanosecond;
   c) more than 1 nanosecond; d) cannot be decided.

6. When Alice flies past Bob again, Bob sends two flashes of light towards Alice according to his clock within 1 nanosecond. What interval between flashes will Alice measure?

a) Less than 1 nanosecond; b) exactly 1 nanosecond;
c) more than 1 nanosecond; d) cannot be decided.

IV. Graphs labelled by the letters a), b), c), d) show the dependence of the length of a rod moving around us on its speed or the dependency of the kinetic energy of a moving particle on its speed. The horizontal axis always shows the velocity v of the body, the vertical axis represents either the length of the rod or the kinetic energy of the particle.



7. Which of the graphs shows the length of a moving rod in classical physics?
8. Which of the graphs shows the length of a moving rod in relativistic physics?
9. Which of the graphs shows the kinetic energy of a moving particle in classical physics?
10. Which of the graphs shows the kinetic energy of a moving particle in relativistic physics?

V. Let us have two inertial frames of reference S and S' moving uniformly in a straight line with respect to each other at a speed close to c. We placed the same length scales and the same clocks in both systems in the direction of the relative speed of the systems.

11. What can an observer in the S system say about the scale and clock in the S' system?

a) The scale has shortened and the clock runs faster;
b) the scale has shortened and the clock runs slower;
c) the scale has lengthened and the clock runs faster;
d) the scale has lengthened and the clock runs slower.

12. Let us have two inertial frames of reference S and S' moving relatively uniformly and rectilinearly at a speed close to c. We have placed the same length scales and the same clocks in both systems. An observer in S' detects two events occurring at the same place. Do these events occur at the same place in S?

a) No, there will never be local events in system S.
b) Yes, in any case.
c) Only at low relative speed of the systems.
d) Only if the events are simultaneous in S'.

VI. Let us have two inertial systems S and S', whose axes are parallel. The system S' moves with respect to the system S at a speed $v = 0.750c$ in the direction of the x-axis.

13. A 12.0 m long rod is placed parallel to the x' axis in the S' system. What will be the length of the rod in the S system?

a) 12.0 m; b) 10.4 m; c) 7.94 m; d) 18.1 m.

14. A rod with a length of 12.0 m is placed parallel to the y' axis in the S' system. What will be the length of the rod in the S system?

a) 12.0 m; b) 10.4 m; c) 7.94 m; d) 18.1 m.

15. At a given point in the system S', an event occurred that lasted 10.0 s for an observer in the system S. What time did the event last for observers in the S' system?

a) 15.1 s; b) 6.61 s; c) 10.0 s; d) 8.66 s.

16. A body with a rest mass of 10.0 kg is placed in the system S'. What relativistic mass has a body in the S system?

a) 15.1 kg; b) 6.61 kg; c) 10.0 kg; d) 8.66 kg.

VII. The inertial system S' moves with respect to the system S with speed $v = c/5$. In the system S' moves the particle with speed $u' = c/3$. The vectors $\boldsymbol{v}$ and $\boldsymbol{u'}$ are parallel.

17. If the directions of the velocities $\boldsymbol{v}$ and $\boldsymbol{u'}$ are opposite, what will be the magnitude of the velocity (speed) of the particle relative to the reference frame S according to classical physics?

a) $c/7$; b) $2c/15$; c) $2c/3$; d) $8c/15$.

18. If the directions of the velocities $\boldsymbol{v}$ and $\boldsymbol{u'}$ are the same, what will be the relative velocity of the particle in S reference frame according to classical physics?

a) $c/2$; b) $2c/15$; c) $8c/15$; d) $c/7$.

19. If the directions of the velocities $\boldsymbol{v}$ and $\boldsymbol{u'}$ are opposite, what will be the magnitude of the velocity of the particle relative to S reference frame according to relativistic physics?

a) $c/7$; b) $2c/15$; c) $c/2$; d) $c/5$.

20. If the directions of the velocities $\boldsymbol{v}$ and $\boldsymbol{u'}$ are the same, what will be the relative velocity of the particle in the S reference frame according to relativistic physics?

a) $c/7$; b) $2c/3$; c) $8c/15$; d) $c/2$.

VIII. With respect to the reference frame S, a particle with rest mass m_0 moves uniformly in along a straight line with a constant speed $v = 0.600c$.

21. What is the total energy of the particle relative to the S reference frame?

a) $0.8m_0c^2$; b) m_0c^2; c) $1.25m_0c^2$; d) $0.25m_0c^2$.

22. What is the kinetic energy of the particle relative the S reference frame?

a) $0.8m_0c^2$; b) m_0c^2; c) $1.25m_0c^2$; d) $0.25m_0c^2$.

23. What is the rest energy of a particle?

a) equal to zero; b) m_0c^2; c) $0.5m_0c^2$; d) $0.25m_0c^2$.

24. What is the momentum of the particle relative to the S reference frame?

a) $0.6m_0c$; b) $0.75m_0c$; c) $0.48m_0c$; d) $0.8m_0c$.

Answers:

1	C	9	C	17	B
2	C	10	A	18	C
3	D	11	B	19	A
4	D	12	D	20	D
5	C	13	C	21	C
6	C	14	A	22	D
7	B	15	B	23	B
8	D	16	A	24	B