

Chapter	11 Special Theory of Relativity	Class	1 st Year	Subject	Physics
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Give Short Answers of the Following Questions

1. What is meant by inertial frame of reference and a non-inertial frame of reference?

Ans. Inertial Frame of Reference:

The frame of reference which is at rest or moving with uniform velocity is called inertial frame of reference. (i.e. $a = 0$)

Examples:

- Earth may be considered as an inertial frame of reference.
- A body placed in a car moving with uniform velocity with respect to earth also remains at rest, that car is also an inertial frame of reference.

Non-inertial Frame of Reference:

The frame of reference which is moving with some acceleration is called non-inertial frame of reference. (i.e. $a \neq 0$)

Examples:

- When a car is moving and suddenly the brakes are applied. Then the body placed in it no longer remains at rest. So due to acceleration car is an accelerated frame of reference.
- Earth is rotating and revolving and hence strictly speaking, the earth is not an inertial frame. But it can often be treated as an inertial frame without serious error because of very small acceleration.

2. What are the two postulates of special theory of relativity?

Ans. Special theory of relativity has two postulates, which can be stated as follows;

- **1st Postulate: (Principle of Relativity)**

The laws of physics are the same in all inertial frames

- **2nd Postulate: (Principle of Constancy of Light)**

The speed of light in free space has the same value for all observers, regardless of the state of motion of the source or the observer.

3. Describe why it is impossible for a material particle to move with speed of light.

Ans. As

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

If speed of the material object is equal to the speed of light (i.e., $v = c$) then

$$m = \frac{m_0}{\sqrt{1 - \frac{c^2}{c^2}}} = \frac{m_0}{\sqrt{1 - 1}} = \frac{m_0}{0} = \infty$$

As infinite mass requires an infinite force to accelerate it. As the infinite force is not available. So an object cannot be accelerated to the speed of light in free space.

4. Does theory of relativity contradict Newton's laws of motion? Explain briefly.

Ans. No, relativistic theory agrees with Newton's laws of motion under limitation on the speed.

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Explanation

For bodies moving at low speeds as compare to speed of light, the relativistic changes in results are negligibly small. Whereas at high speeds, the exact result can't explain without considering the relativistic results into account.

In our everyday life we deal with extremely small speeds compared to the speed of light. Even the earth's orbital speed is 30 km s^{-1} . On the other hand, the speed of light in free space is $300,000 \text{ km s}^{-1}$ or $3 \times 10^5 \text{ km s}^{-1}$. This is the reason why Newton's laws are valid in everyday situations. However, when we deal with atomic particles moving with velocities approaching speed of light, the relativistic effects are very prominent and experimental results cannot be explained without taking Einstein's equations into account.

5. What is meant by proper time, and proper length?

Ans. Proper Time: The time measured by a clock that is at rest with respect to the observer. It is the time experienced by the observer in their own rest frame.

Proper Length: The length of an object measured by an observer who is at rest with respect to the object. It is the length of the object in its own rest frame.

6. What is meant by relativistic mass, length and time?

Ans. Relativistic Mass:

The mass of an object increases as its speed approaches the speed of light.

If is m_0 the rest mass and m is the relativistic mass then

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \text{so } m > m_0 \text{ i.e. relativistic mass is greater then proper mass}$$

Relativistic Length:

The length of an object appears to contract as its speed approaches the speed of light.

If is L_0 the proper length and L is the relativistic length then

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}} \quad \text{so } L < L_0 \text{ i.e. relativistic length is smaller then proper length}$$

Relativistic Time:

Time appears to pass more slowly for an observer in motion relative to a stationary observer.

If is t_0 the proper time and t is the relativistic time then

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \text{so } t > t_0 \text{ i.e. relativistic time is greater then proper time}$$

7. Why mass of a moving object increases?

Ans. according to special theory of relativity, mass and energy are different physical quantities but are inter-convertible. It can be expressed as,

$$E = mc^2$$

The energy equivalent of an object's mass at rest is called rest mass energy. It can be expressed as,

$$E_0 = m_0 c^2$$

As mc^2 is greater than $m_0 c^2$. So difference of energy represents the K.E.

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$$K.E = mc^2 - m_0c^2$$

Or $K.E = (m - m_0) c^2$

$$K.E = \Delta mc^2$$

The change in mass m due to change in energy ΔE is given by

$$\Delta E = \Delta mc^2$$

$$\Delta m = \frac{\Delta E}{c^2}$$

As c^2 is very large quantity, so for a change in mass, change in energy should be very large. As, in everyday world, energy changes are very small, therefore, the changes in mass too small to be measured.

8. All motion are relatives. Does space-time is absolute? Explain briefly.

Ans. No, space time is not absolute. According to Einstein's theory of relativity, space time is:

Relative: Its geometry and measurement depend on the observer's frame of reference.

Dynamic: It's curved by the presence of mass and energy.

Flexible: Its fabric is shaped by the objects within it.

9. Explain that speed of light is an ultimate limit for an object.

Ans. The speed of light is the ultimate limit for any object. If $v = c$, then equations of special theory of relativity reduce to:

$$(1) \quad t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{t_0}{\sqrt{1 - \frac{c^2}{c^2}}} = \frac{t_0}{\sqrt{1-1}} = \frac{t_0}{0} = \infty$$

$$(2) \quad L = L_0 \sqrt{1 - \frac{v^2}{c^2}} = L_0 \sqrt{1 - \frac{c^2}{c^2}} = L_0 \sqrt{1-1} = 0$$

$$(3) \quad m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{m_0}{\sqrt{1 - \frac{c^2}{c^2}}} = \frac{m_0}{\sqrt{1-1}} = \frac{m_0}{0} = \infty$$

As these results are not practically possible, so in practice speed limit of an object is that it is always less than c .

10. Give examples where the results of special theory of relativity have been verified.

Ans. The amazing result applies to all timing processes e.g., physical, chemical and biological processes. Even the aging process of the human body is slowed by motion at very high speed.

For example: If a traveler on a plane moving at $0.8c$ picks up and opens a book, the event takes one second as measured by the traveler. However, to a person standing outside the plane, the same event takes 1.7 seconds.

The distance from earth to a star measured by an observer in a moving space-ship would seem smaller than that the distance measured by an observer on earth frame.

Example: Let a train that is measured to be 100 metres long when at rest travel at 80% of the speed of light ($0.8c$). A person inside the train will measure its length as 100 metres. However, a person standing by the side of the track will observe the train to be only 60 metres long. This effect of relativity, which is the shortening of length in the direction of motion, is due to length

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contraction.

Energy-mass changes in nuclear reactions are exactly in accordance to above mentioned equations.