Access Tuition

A-Level Physics

Einstein's Theory of Special Relativity

Question Paper

Time available: 30 minutes
Marks available: 24 marks

1. (a) State what is meant by an inertial frame of reference.

_____

_____

_____

(1)

(b) A pair of detectors is set up to measure the intensity of a parallel beam of unstable particles.
In the reference frame of the laboratory, the detectors are separated by a distance of 45 m.
The speed of the particles in the beam is $0.97c$.

The intensity of the beam at the second detector is 12.5% of the intensity at the first detector.

Calculate the half-life of the particles in the reference frame in which they are at rest.

half-life = _____ s

(4)

(c) In calculations involving time dilation, it is important to identify proper time.

Identify the proper time in the calculation in part (b).
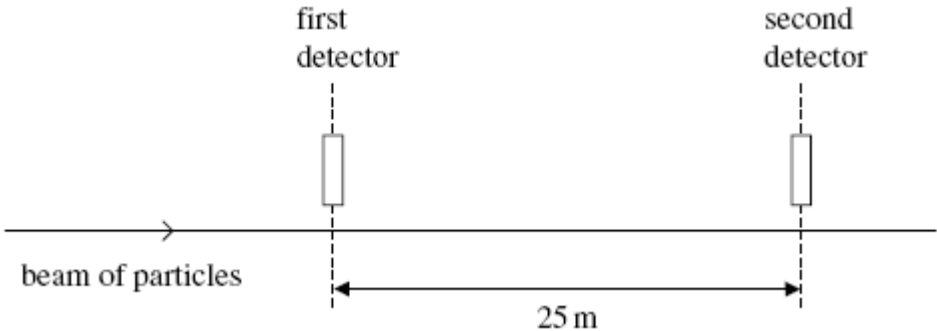
_____

_____

_____

(1)
(Total 6 marks)

2. (a) One of the two postulates of Einstein's theory of special relativity is that the speed of light in free space, *c*, is invariant.

Explain what is meant by this statement.

_____

_____

_____

(1)

(b) A beam of identical particles moving at a speed of 0.98*c* is directed along a straight line between two detectors 25 m apart.

The particles are unstable and the intensity of the beam at the second detector is a quarter of the intensity at the first detector.

Calculate the half-life of the particles in their rest frame.

answer = _____ s

(4)
(Total 5 marks)

3. (a) Calculate the speed at which a matter particle has a mass equal to 10 times its rest mass.

_____

_____

_____

_____

_____

_____

(3)

(b) Explain why a matter particle can not travel as fast as a photon in free space even though its kinetic energy can be increased without limit.

_____

_____

_____

_____

_____

_____

_____

_____

(3)
(Total 6 marks)

4. (a) A muon travels at a speed of 0.95c relative to an observer.

The muon travels a distance of 2.5 × 10^3 m between two points in the frame of reference of the observer.

Calculate the distance between these two points in the frame of reference of the muon.

distance = _____ m

(2)

(b) Measurements of muons created by cosmic rays can be used to demonstrate relativistic time dilation.

State the measurements made and the observation that provides evidence for relativistic time dilation.

_____

_____

_____

_____

_____

_____

(2)

(c)   As the muons travel through the atmosphere, their speeds are reduced by interaction with the particles in the air.

Discuss, with reference to relativity, the effect that this reduction of speed has on the rate of detection of the muons on the surface of the Earth.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)
(Total 7 marks)