



A-Level Physics

Length Contraction

Question Paper

Time available: 45 minutes

Marks available: 26 marks

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1.

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

(i) Explain what is meant by this postulate.

(ii) State and explain the other postulate.

(4)

(b) A stationary muon has a rest mass of 1.88×10^{-28} kg and a half-life of 2.2×10^{-6} s.

Calculate

(i) the mass of a muon travelling at $0.996 c$, where c is the speed of light in a vacuum,

(ii) the distance, in a laboratory frame of reference, travelled in one half-life by a muon moving at $0.996 c$.

(6)

(Total 10 marks)

2.

In a particle beam experiment, a pulsed beam of protons at a speed of $1.00 \times 10^8 \text{ m s}^{-1}$ passed through a stationary detector in a time of 15.0 ns.



(a) Calculate the length of the pulsed beam in

(i) the frame of reference of the detector,

(ii) the frame of reference of the protons.

(3)

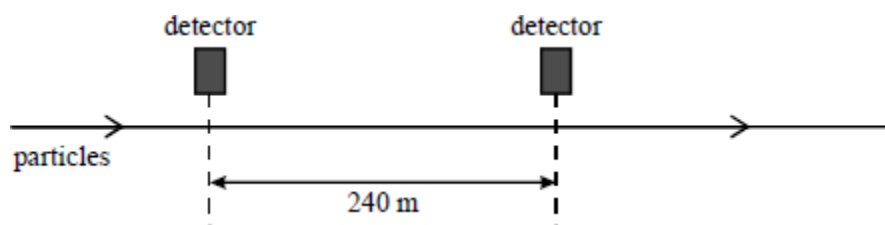
(b) (i) Calculate the kinetic energy of each proton in the beam, in J.

(ii) The beam consisted of 10^7 protons. It passed through the detector and was stopped by a stationary target. Calculate the average power which the proton beam delivered to the target during the pulse.

(5)
(Total 8 marks)

3.

- (a) In a particle beam experiment, a short pulse of 1 ns duration of particles moving at constant speed passed directly between 2 detectors at a fixed distance apart of 240 m. The pulse took $0.84 \mu\text{s}$ to travel from one detector to the other.



- (i) Calculate the speed of the particles.

- (ii) Calculate the distance between the two detectors in the frame of reference of the particles.

(4)

(b) In a 'thought experiment' about relativity, a student stated that a twin who travelled from the Earth to a distant planet and back at a speed close to the speed of light would be the same age on return as the twin who stayed on Earth. Explain why this statement is **not** correct.

(4)
(Total 8 marks)