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Mahindra University Hyderabad
École Centrale School of Engineering
Minor - II Examination

Program: B. Tech   Branch: CSE/ARI/CAM/ECM/ECE   Year: III   Semester: 2
Subject:- An introduction to Spacetime Physics (PH3203)

Date: 24/04/2025   Start Time: 04:45 PM
Max. Marks: 40 marks   End Time: 06:15 PM

Instructions:

- Answer all the questions.
- All the best!

Section-I : MCQs. Please explain your answers. (5 x 2 = 10 marks)

Q1:   (2 M)

Which of the following statements is NOT a consequence of the Lorentz transformation equations?

(A) Time intervals are invariant between inertial frames

(B) Simultaneity is relative to the observer's frame

(C) The speed of light is constant in all inertial frames

(D) Moving clocks tick more slowly than stationary ones

Q2:   (2 M)

A spaceship is moving directly toward Earth at a speed of $0.5c$. The crew of the spaceship emits a laser beam aimed at Earth. According to the crew, the laser beam travels at speed c. What speed does an observer on Earth measure for the laser beam?

(A) $0.5c$

(B) $1.5c$

(C) c

(D) It depends on the observer's position

Q3: (2 M)

In the Pole-Barn paradox, a runner with a 20 m pole runs toward a 10 m barn at relativistic speed. From the barn frame, the pole fits entirely inside due to length contraction. What explains the apparent contradiction in the runner's frame?

(A) The pole actually shrinks physically

(B) The barn contracts even more in the runner's frame

(C) The events of the front and back of the pole entering the barn are simultaneous in all frames

(D) The doors of the barn do not close simultaneously in the runner's frame

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Q4: (2 M)

In an inertial frame, two clocks are synchronized and placed at either end of a 1 km long train. To an observer on the ground, the train is moving at a high speed. What does the ground observer conclude about the two clocks on the train?

(A) The clocks are synchronized

(B) The clock at the front is ahead of the one at the rear

(C) The clock at the rear is ahead of the one at the front

(D) Both clocks tick faster than ground clocks

Q5: (2 M)

Which of the following quantities is Lorentz invariant (i.e., has the same value in all inertial frames)?

(A) The time interval between two events

(B) The length of an object

(C) The speed of a particle

(D) The spacetime interval between two events

Section-II : Answer all the questions (30 marks)

$(4 + 1 = 5 \text{ M})$

Q6:

Two firecrackers explode on a moving train. In the train's rest frame S', the explosions occur at positions 0 m and 10 m, and they are simultaneous (i.e., they both occur at time $t' = 0$). An observer on the platform (frame S) sees the train moving to the right at speed $v = 0.6c$.

(a) What is the <u>spatial and temporal separation</u> between the two explosions as measured by the platform observer (i.e., in frame S)?

(b) According to the platform observer, which explosion occurred first?

(Use the Lorentz transformation equations.)

(5 M)

Q7:

Hydrogen gas near the center of our galaxy is orbiting a black hole and moving directly away from Earth. As a result, the light it emits is redshifted. The radiation we detect has a wavelength of $1900 nm$, whereas the original emitted wavelength was $1875 nm$. What is the speed of the hydrogen gas relative to Earth?

(6 M)

Q8:

A spaceship at rest in a certain reference frame S is given a speed increment of $0.50c$. Relative to its new rest frame, it is then given a further $0.50c$ increment. This process is continued until its speed with respect to its original frame S exceeds $0.999c$. How many increments does this process require?

$(3 + 3 + 4 + 4 = 14 \text{ M})$

Q9:

On their 21st birthday, one twin, Alex, gets on a moving sidewalk, which carries her out to star X at speed $4/5c$. Her twin brother, Blake, stays home. When Alex gets to star X, she immediately jumps onto the returning (inbound) moving sidewalk and comes back to earth, again at speed $4/5c$. She arrives on her 39th birthday (as determined by her watch).

1. How old is her twin brother Blake?

2. From Blake's perspective, how far away is star X?

3. Assume the outbound sidewalk system S' and the inbound one S" (the earth system is S). All three frames synchronize their master clocks and choose their origins at the location of Earth so that all origins are centered at $t = t' = t'' = 0$. What are the coordinates (x, ct) of the jump (from the outbound to inbound sidewalk) in S (Blake's frame)?

4. What are the coordinates (x'', ct'') of the jump in S" (Alex's inbound frame)?

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