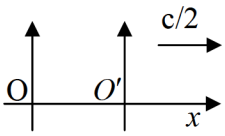
Chapter 1 (Lorentz Transformations)

PYQ [IIT-JAM]

Q1. Two frames, O and O', are in relative motion as shown. O' is moving with speed $c/2$, where c is the speed of light. In frame O, two separate events occur at (x_1, t_1) and (x_2, t_2). In frame O', these events occur simultaneously. The value of $(x_2 - x_1)/(t_2 - t_1)$ is



(a) $c/4$ (b) $c/2$ (c) $2c$ (d) c

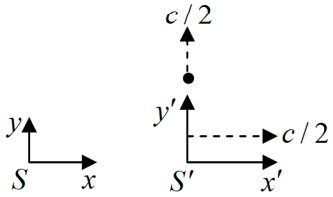
IIT-JAM 2014

Q2. A proton from outer space is moving towards earth with velocity $0.99c$ as measured in earth's frame. A spaceship, traveling parallel to the proton, measures proton's velocity to be $0.97c$. The approximate velocity of the spaceship in the earth's frame, is

(a) $0.2c$ (b) $0.3c$ (c) $0.4c$ (d) $0.5c$

IIT-JAM 2015

Q3. Consider an inertial frame S' moving at speed $\frac{c}{2}$ away from another inertial frame S along the common x-x' axis, where c is the speed of light. As observed from S', a particle is moving with speed $\frac{c}{2}$ in the y' direction, as shown in the figure. The speed of the particle as seen from S is:



(a) $\frac{c}{\sqrt{2}}$ (b) $\frac{c}{2}$ (c) $\frac{\sqrt{7}c}{4}$ (d) $\frac{\sqrt{3}c}{5}$

IIT-JAM 2017

Q4. Two events E_1 and E_2 take place in an inertial frame S with respective time space coordinates (in SI units): $E_1(t_1 = 0, \vec{r}_1 = 0)$ and $E_2(t_2 = 0, x_2 = 10^8, y_2 = 0, z_2 = 0)$. Another inertial frame S' is moving with respect to S with a velocity $\vec{v} = 0.8c\hat{i}$. The time difference $(t_2' - t_1')$ as observed in S' is _____ s.

(Specify your answer in seconds upto two digits after the decimal point)

IIT-JAM 2018

Q5. Which of the following statement(s) is/are true?

(a) Newton's laws of motion and Maxwell's equations are both invariant under Lorentz transformations

(b) Newton's laws of motion and Maxwell's equations are both invariant under Galilean transformations

(c) Newton's laws of motion are invariant under Galilean transformations and Maxwell's equations are invariant under Lorentz transformations

(d) Newton's laws of motion are invariant under Lorenz transformations and Maxwell's equations are invariant under Galilean transformations

IIT-JAM 2019

Q6. In an inertial frame S, a stationary rod makes an angle θ with the x-axis. Another inertial frame S' moves with a velocity v with respect to S along the common x-x' axis. As observed from S' the angle made by the rod with the x' - axis is θ'. Which of the following statement is correct?

(a) $\theta' > \theta$

(b) $\theta' > \theta$

(c) $\theta' > \theta$ if v is negative and $\theta' > \theta$ if v is positive

(d) $\theta' > \theta$ if v is negative and $\theta' < \theta$ if v is positive

IIT-JAM 2008

Q7. Light takes 4 hours to cover the distance from Sun to Neptune. If you travel in a spaceship at a speed $0.99c$ (where c is the speed of light in vacuum), the time (in minutes) required to cover the same distance measured with a clock on the spaceship will be approximately

(a) 34 (b) 56 (c) 85 (d) 144

IIT-JAM 2012

Q8. Muons are elementary particles produced in the upper atmosphere. They have a life time of $2.2\mu s$. Consider muons which are traveling vertically towards the earth's surface at a speed of $0.998c$. For an observer on earth, the height of the atmosphere above the surface of the earth is $10.4\,km$. Which of the following statements are true?

(a) The muons can never reach earth's surface

(b) The apparent thickness of earth's atmosphere in muon's frame of reference is $0.96\,km$

(c) The lifetime of muons in earth's frame of reference is $34.8\mu s$

(d) Muons traveling at a speed greater than $0.998\ c$ reach the earth's surface

IIT-JAM 2015

Q9. Rod R_1 has a rest length $1m$ and rod R_2 has a rest length of $2m$. R_1 and R_2 are moving with respect to the laboratory frame with velocities $+v\hat{i}$ and $-v\hat{i}$, respectively. If R_2 has a length of $1m$ in the rest frame of R_1, $\frac{v}{c}$ is given by_____

(Specify your answer upto two digits after the decimal point)

IIT-JAM 2018

Q10. A space crew has a life support system that can last only for 1000 hours. What minimum speed would be required for safe travel of the crew between two space stations separated by a fixed distance of $1.08\times10^{12}\ km$?

(a) $\frac{c}{\sqrt{3}}$ (b) $\frac{c}{\sqrt{2}}$ (c) $\frac{c}{2}$ (d) $\frac{c}{\sqrt{5}}$

IIT-JAM 2009

Q11. A rod is moving with a speed of $0.8c$ in a direction at 60° to its own length. The percentage contraction in the length of the rod is_____

IIT-JAM 2015

Q12. Three events, $E_1\left(ct=0,x=0\right), E_2\left(ct=0,x=L\right)$ and $E_3\left(ct=0,x=-L\right)$ occur, as observed in an inertial frame S. Frame S' is moving with a speed v along the positive x- direction with respect to S. In S', let t_1', t_2', t_3' be the respective times at which E_1, E_2 and E_3 occurred. Then,

(a) $t_2' < t_1' < t_3'$ (b) $t_1' = t_2' = t_3'$ (c) $t_3' < t_1' < t_2'$ (d) $t_3' < t_2' < t_1'$

IIT-JAM 2021

PYQ [GATE]

Q1. For the set of all Lorentz transformations with velocities along the x-axis consider the two statements given below:

P: If L is a Lorentz transformation, then, L^{-1} is also a Lorentz transformation.

Q: If L_1 and L_2 are Lorentz transformations, then $L_1 L_2$ is necessarily a Lorentz transformation.

Choose the correct option

(a) P is true and Q is false (b) Both P and Q are true

(c) Both P and Q are false (d) P is false and Q is true

GATE- 2010

Q2. A π^0 meson at rest decays into two photons, which moves along the x-axis. They are both detected simultaneously after a time, $t = 10s$. In an inertial frame moving with a velocity $v = 0.6c$ in the direction of one of the photons, the time interval between the two detections is

(a) $15c$ (b) $0s$ (c) $10s$ (d) $20s$

GATE- 2010

Q3. A rod of proper length l_0 oriented parallel to the *x*-axis moves with speed $2c/3$ along the x-axis in the S-frame, where c is the speed of light in free space. The observer is also moving along the x-axis with speed $c/2$ with respect to the S-frame. The length of the rod as measured by the observer is

(a) $0.35l_0$ (b) $0.48l_0$ (c) $0.87l_0$ (d) $0.97l_0$

GATE- 2012

Q4. An electron is moving with a velocity of $0.85c$ in the same direction as that of a moving photon. The relative velocity of the electron with respect to photon is

(a) c (b) $-c$ (c) $0.15c$ (d) $-0.15c$

GATE- 2013

Q5. If the half-life of an elementary particle moving with speed 0.9c in the laboratory frame is $5\times10^{-8}s$, then the proper half-life is _____ $\times10^{-8}$ s. $\left(c = 3\times10^8 m/s\right)$

GATE- 2014

Q6. In an inertial frame S, two events A and B take place at $(ct_A = 0, \vec{r}_A = 0)$ and $(ct_B = 0, \vec{r}_B = 2\hat{y})$, respectively. The times at which these events take place in a frame S' moving with a velocity $0.6c\,\hat{y}$ with respect to S are given by

(a) $ct'_A = 0;\ ct'_B = -\frac{3}{2}$ (b) $ct'_A = 0;\ ct'_B = 0$

(c) $ct'_A = 0;\ ct'_B = \frac{3}{2}$ (d) $ct'_A = 0;\ ct'_B = \frac{1}{2}$

GATE- 2015

Q7. In an inertial frame of reference S, an observer finds two events occurring at the same time at coordinates $x_1 = 0$ and $x_2 = d$. A different inertial frame S' moves with velocity v with respect to S along the positive x-axis. An observer in S' also notices these two events and finds them to occur at times t'_1 and t'_2 and at positions x'_1 and x'_2 respectively. If $\Delta t' = t'_2 - t'_1, \Delta x' = x'_2 - x'_1$ and $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$, which of the following statements is true?

(a) $\Delta t' = 0, \Delta x' = \gamma d$ (b) $\Delta t' = 0, \Delta x' = \frac{d}{\gamma}$

(c) $\Delta t' = \frac{-\gamma v d}{c^2}, \Delta x' = \gamma d$ (d) $\Delta t' = \frac{-\gamma v d}{c^2}, \Delta x' = \frac{d}{\gamma}$

GATE- 2016

Q8. An object travels along the x-direction with velocity $\frac{c}{2}$ in a frame O. An observer in a frame O' sees the same object travelling with velocity $\frac{c}{4}$. The relative velocity of O' with respect to O in units of c is..... (up to two decimal places).

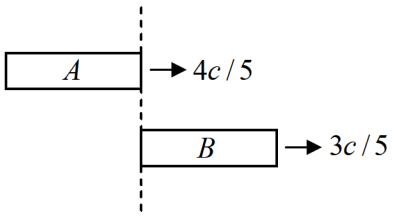
GATE- 2017

Q9. A spaceship is travelling with a velocity of $0.7c$ away from a space station. The spaceship ejects a probe with a velocity $0.59c$ opposite to its own velocity. A person in the space station would see the probe moving at a speed Xc, where the value of X is _____ (up to three decimal places).

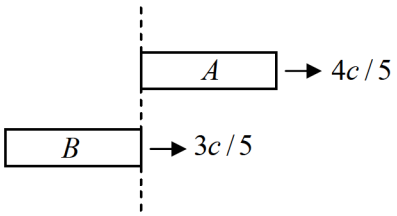
GATE - 2018

Q10. Two spaceships A and B, each of the same rest length L, are moving in the same direction with speeds $\frac{4c}{5}$ and $\frac{3c}{5}$, respectively, where c is the speed of light. As measured by B, the time taken by A to completely overtake B [see figure below] in units of L/c (to the nearest integer) is _____

(i)



(ii)



GATE - 2019

Q11. Two events, one on the earth and the other one on the Sun, occur simultaneously in the earth's frame. The time difference between the two events as seen by an observer in a spaceship moving with velocity $0.5c$ in the earth's frame along the line joining the earth to the Sun is Δt, where c is the speed of light. Given that light travels from the Sun to the earth in 8.3 minutes in the earth's frame, the value of $|\Delta t|$ in minutes (rounded off to two decimal places) is_____

(Take the earth's frame to be inertial and neglect the relative motion between the earth and the sun)

GATE - 2019

PYQ [NET-JRF]

Q1. Two events separated by a (spatial) distance $9\times10^{9}\,m$, are simultaneous in one inertial frame. The time interval between these two events in a frame moving with a constant speed $0.8\,c$ (where the speed of light $c=3\times10^{8}\,m/s$) is

(a) $60\,s$ (b) $40\,s$ (c) $20\,s$ (d) $0\,s$

NET/JRF (DEC-2012)

Q2. An inertial observer sees two events E_1 and E_2 happening at the same location but $6\,\mu s$ apart in time. Another observer moving with a constant velocity v (with respect to the first one) sees the same events to be $9\,\mu s$ apart. The spatial distance between the events, as measured by the second observer, is approximately

(a) $300\ m$ (b) $1000\ m$ (c) $2000\ m$ (d) $2700\ m$

NET/JRF (June-2017)

Q3. Let (x,t) and (x',t') be the coordinate systems used by the observers O and O', respectively. Observer O' moves with a velocity $v=\beta c$ along their common positive x - axis. If $x_{+}=x+ct$ and $x_{-}=x-ct$ are the linear combinations of the coordinates, the Lorentz transformation relating O and O' takes the form

(a) $x'_{+}=\dfrac{x_{-}-\beta x_{+}}{\sqrt{1-\beta^2}}$ and $x'_{-}=\dfrac{x_{+}-\beta x_{-}}{\sqrt{1-\beta^2}}$ (b) $x'_{+}=\sqrt{\dfrac{1+\beta}{1-\beta}}x_{+}$ and $x'_{-}=\sqrt{\dfrac{1-\beta}{1+\beta}}x_{-}$

(c) $x'_{+}=\dfrac{x_{+}-\beta x_{-}}{\sqrt{1-\beta^2}}$ and $x'_{-}=\dfrac{x_{-}-\beta x_{+}}{\sqrt{1-\beta^2}}$ (d) $x'_{+}=\sqrt{\dfrac{1-\beta}{1+\beta}}x_{+}$ and $x'_{-}=\sqrt{\dfrac{1+\beta}{1-\beta}}x_{-}$

NET/JRF (June-2016)

Q4. The area of a disc in its rest frame S is equal to 1 (in some units). The disc will appear distorted to an observer O moving with a speed u with respect to S along the plane of the disc. The area of the disc measured in the rest frame of the observer O is (c is the speed of light in vacuum)

(a) $\left(1-\dfrac{u^2}{c^2}\right)^{1/2}$ (b) $\left(1-\dfrac{u^2}{c^2}\right)^{-1/2}$ (c) $\left(1-\dfrac{u^2}{c^2}\right)$ (d) $\left(1-\dfrac{u^2}{c^2}\right)^{-1}$

NET/JRF (JUNE-2013)

Q5. Consider three inertial frames of reference A, B and C. the frame B moves with a velocity $\frac{c}{2}$ with respect to A, and C moves with a velocity $\frac{c}{10}$ with respect to B in the same direction. The velocity of C as measured in A is

(a) $\frac{3c}{7}$ (b) $\frac{4c}{7}$ (c) $\frac{c}{7}$ (d) $\frac{\sqrt{3}c}{7}$

NET/JRF (June-2015)

Q6. A relativistic particle moves with a constant velocity v with respect to the laboratory frame. In time τ, measured in the rest frame of the particle, the distance that it travels in the laboratory frame is

(a) $v\tau$ (b) $\frac{c\tau}{\sqrt{1-\frac{v^2}{c^2}}}$ (c) $v\tau\sqrt{1-\frac{v^2}{c^2}}$ (d) $\frac{v\tau}{\sqrt{1-\frac{v^2}{c^2}}}$

NET/JRF (DEC-2016)

Q7. A light signal travels from a point A to a point B, both within a glass slab that is moving with uniform velocity (in the same direction as the light) with speed $0.3c$ with respect to an external observer. If the refractive index of the slab is 1.5, then the observer will measure the speed of the signal as

(a) $0.67c$ (b) $0.81c$ (c) $0.97c$ (d) c

NET/JRF (DEC-2017)

Q8. Two particles A and B move with relativistic velocities of equal magnitude v, but in opposite directions, along the x-axis of an inertial frame of reference. The magnitude of the velocity of A, as seen from the rest frame of B, is

(a) $\frac{2v}{\left(1-\frac{v^2}{c^2}\right)}$ (b) $\frac{2v}{\left(1+\frac{v^2}{c^2}\right)}$ (c) $2v\sqrt{\frac{c-v}{c+v}}$ (d) $\frac{2v}{\sqrt{1-\frac{v^2}{c^2}}}$

NET/JRF (JUNE-2018)

Q9. What is proper time interval between the occurrence of two events if in one inertial frame events are separated by $7.5\times10^8\ m$ and occur $6.5\,s$ apart?

(a) $6.50\,s$ (b) $6.00\,s$ (c) $5.75\,s$ (d) $5.00\,s$

NET/JRF (DEC-2012)

PYQ [JEST]

Q1. In a certain inertial frame two light pulses are emitted at point $5\,km$ apart and separated in time by $5\,\mu s$. An observer moving at a speed V along the line joining these points notes that the pulses are simultaneous. Therefore V is

(a) $0.7c$ (b) $0.8c$ (c) $0.3c$ (d) $0.9c$

JEST-2012

Q2. A light beam is propagating through a block of glass with index of refraction n. If the glass is moving at constant velocity v in the same direction as the beam, the velocity of the light in the glass block as measured by an observer in the laboratory is approximately

(a) $u=\frac{c}{n}+v\left(1-\frac{1}{n^2}\right)$ (b) $u=\frac{c}{n}-v\left(1-\frac{1}{n^2}\right)$

(c) $u=\frac{c}{n}+v\left(1+\frac{1}{n^2}\right)$ (d) $u=\frac{c}{n}$

JEST-2013

Q3. In a certain inertial frame two light pulses are emitted, a distance 5 km apart and separated by $5\,\mu s$. An observer who is traveling, parallel to the line joining the points where the pulses are emitted, at a velocity v with respect to this frame notes that the pulses are simultaneous. Therefore v is

(a) $0.7c$ (b) $0.8c$ (c) $0.3c$ (d) $0.9c$

JEST-2014

Q4. A monochromatic wave propagates in a direction making an angle 60° with the x-axis in the reference frame of source. The source moves at speed $v=\frac{4c}{5}$ towards the observer. The direction of the (cosine of angle) wave as seen by the observer is

(a) $\cos\theta'=\frac{13}{14}$ (b) $\cos\theta'=\frac{3}{14}$ (c) $\cos\theta'=\frac{13}{6}$ (d) $\cos\theta'=\frac{1}{2}$

JEST-2014

Q5. The distance of a star from the Earth is 4.25 light years, as measured from the Earth. A space ship travels from Earth to the star at a constant velocity in 4.25 years, according to the clock on the ship. The speed of the space ship in units of the speed of light is,

(a) $\frac{1}{2}$ (b) $\frac{1}{\sqrt{2}}$ (c) $\frac{2}{3}$ (d) $\frac{1}{\sqrt{3}}$

JEST-2015

Q6. Light takes approximately 8 minutes to travel from the Sun to the Earth. Suppose in the frame of the Sun an event occurs at $t=0$ at the Sun and another event occurs on Earth at $t=1$ minute. The velocity of the inertial frame in which both these events are simultaneous is:

(a) $\frac{c}{8}$ with the velocity vector pointing from Earth to Sun

(b) $\frac{c}{8}$ with the velocity vector pointing from Sun to Earth

(c) The events can never be simultaneous - no such frame exists

(d) $c\sqrt{1-\left(\frac{1}{8}\right)^2}$ with velocity vector Pointing from to Earth

JEST-2016

Q7. A person on Earth observes two rockets A and B directly approaching each other with speeds $0.8c$ and $0.6c$ respectively. At a time when the distance between the rockets is observed to be $4.2\times10^8\ m$, the clocks of the rockets and the Earth are synchronized to $t=0s$. The time of collision (in seconds) of the two rockets as measured in rocket $A's$ frame is $\frac{x}{10}$. What is x?

JEST-2018