

Chapter 1 (Lorentz Transformation) Worksheet

Q1. In a system of units in which the velocity of light $c=1$, which of the following is a Lorentz transformation?

- (a) $x' = 4x, y = y', z' = z, t' = 0.25t$
 (b) $x' = x - 0.5t, y = y', z' = z, t' = t + x$
 (c) $x' = 1.25x - 0.75t, y' = y, z' = z, t' = 0.75t - 1.25x$
 (d) $x' = 1.25x - 0.75t, y' = y, z' = z, t' = 1.25t - 0.75x$

Q2. If $u(x, y, z, t) = f(x + i\beta y - vt) + g(x - i\beta y - vt)$, where f and g are arbitrary and twice differentiable functions, is a solution of the wave equation

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = \frac{1}{c^2} \frac{\partial^2 u}{\partial t^2}, \text{ then } \beta \text{ is}$$

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

Q3. Two events in S frame is separated by space coordinate $x_2 - x_1 = L$ and by time coordinate $t_2 - t_1 = T$. What will be difference in space coordinate measured from S' which is moving with speed v with respect to S frame

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

Q4. The equation of circle in rest frame of any inertial frame is given by $x^2 + y^2 = a^2$ (in some units).

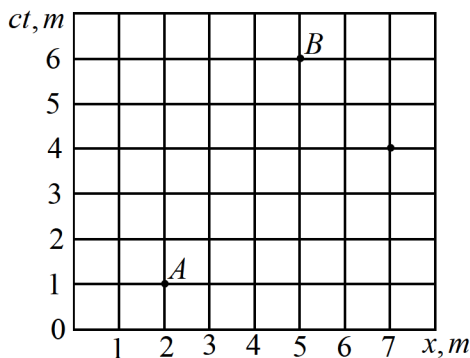
The circle will appear ellipse to an observer O moving with a velocity $u\hat{i}$ with respect to S along the plane of the ellipse. The coordinate of centre of the ellipse is measured in the rest frame of the observer O after time t is (c is the speed of light in vacuum)

- (a) $0, 0$ (b) $(ut, 0)$ (c) $(-ut, 0)$ (d) (ut, ut)

Q5. A relativistic particle moves with a constant velocity $\frac{3}{5}c$ 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 $\alpha\tau c$ so value of α is

- (a) 0.25 (b) 0.75 (c) 1.25 (d) 1.75

- Q6. The space-time diagram of figure shows three events A , B , which occurred on the x -axis of some inertial reference frame.



The time interval between the events A and B in the reference frame where the two events occurred at the same point.

- (a) 0 (b) $1.3 \times 10^{-8} s$ (c) $13 \times 10^{-8} s$ (d) $25 \times 10^{-8} s$
- Q7. 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) $\frac{v\tau}{\sqrt{1-\frac{v^2}{c^2}}}$

- Q8. 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

- (a) 0s (b) 0.22s (c) 0.33s (d) 0.44s

- Q9. A relativistic particle moves with a constant velocity $0.8c$ with respect to the laboratory frame. In time 5sec, measured in the rest frame of the particle, the distance that it travels in the laboratory frame is

- (a) $12 \times 10^8 m$ (b) $19.8 \times 10^8 m$ (c) $7.2 \times 10^8 m$ (d) $6.2 \times 10^8 m$

- Q10. 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. Then find value of $\sqrt{1-\frac{v^2}{c^2}}$

- (a) $\frac{2}{3}$ (b) $\frac{1}{3}$ (c) $\frac{5}{9}$ (d) $\frac{2}{9}$

- Q16. Reference frame B is moving with respect to inertial frame A with velocity $\frac{c}{2}\hat{i}$ and Reference frame C is moving with respect to inertial frame B with velocity $\frac{c}{2}\hat{i}$. Velocity of C with respect to A is given by
- (a) 0 (b) c (c) $\frac{4c}{5}\hat{i}$ (d) $-\frac{4c}{5}\hat{i}$
- Q17. Reference frame B moving with respect to inertial frame A with velocity $\frac{c}{2}\hat{i}$ and Reference frame C moving with respect to inertial frame B with velocity $-\frac{c}{2}\hat{i}$. Velocity of C with respect to A is given by
- (a) 0 (b) c (c) $\frac{4c}{5}\hat{i}$ (d) $-\frac{4c}{5}\hat{i}$
- Q18. Reference frame B is moving with respect to inertial frame A with velocity $\frac{c}{2}\hat{i}$ and Reference frame C is moving with respect to inertial frame B with velocity $\frac{c}{2}\hat{i}$. What is the velocity of C with respect to A ?
- (a) 0 (b) c (c) $\frac{4c}{5}\hat{i}$ (d) $-\frac{4c}{5}\hat{i}$
- Q19. Two particles A and B are moving with velocity $0.8c\hat{i}$ and $-0.4c\hat{i}$ with respect to some inertial frame. The velocity of A from rest frame of B is
- (a) $0.91c$ (b) $-0.91c$ (c) $0.3c$ (d) $-0.3c$
- Q20. 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) $u = \frac{c}{n}$
- Q21. If fluid is moving with velocity v with respect to stationary narrow tube. If light pulse enter into fluid in the direction of flow. What is speed of light pulse measured by observer who is stationary with respect to tube?
- (a) c (b) $\frac{c}{n}$ (c) $\frac{c}{n} \left(\frac{1 + \frac{nv}{c}}{1 + \frac{v}{nc}} \right)$ (d) $\frac{c}{n} \left(\frac{1 + \frac{v}{nc}}{1 + \frac{nv}{c}} \right)$

Q22. A light beam is emitted at an angle θ_0 with respect to the x' in S' frame which is moving with velocity $u\hat{i}$. Then the angle θ the beam makes with respect to x axis in S frame

- (a) $\theta = \theta_0$ (b) $\cos \theta = \frac{u \cos \theta_0}{c}$
 (c) $\cos \theta = \frac{\cos \theta_0 + \frac{u}{c}}{1 + \frac{u}{c} \cos \theta_0}$ (d) $\cos \theta = \frac{1 + \frac{u \cos \theta_0}{c}}{\cos \theta_0 + \frac{u}{c}}$

Q23. A light beam is emitted at an angle θ_0 with respect to the x' in S' frame which is moving with velocity $u\hat{i}$. Then the angle θ the beam makes with respect to x axis in S frame is given by

- (a) $\tan \theta = \frac{u_y}{u_x} = \frac{\sin \theta_0 \sqrt{1 - \frac{u^2}{c^2}}}{1 + \frac{u \cos \theta_0}{c}}$ (b) $\tan \theta = \frac{u_y}{u_x} = \frac{\sin \theta_0 \sqrt{1 + \frac{u^2}{c^2}}}{1 + \frac{u \cos \theta_0}{c}}$
 (c) $\tan \theta = \frac{u_y}{u_x} = \frac{c \sin \theta_0 \sqrt{1 - \frac{u^2}{c^2}}}{c \cos \theta_0 + u}$ (d) $\tan \theta = \frac{1 + \frac{u \cos \theta_0}{c}}{\cos \theta_0 + \frac{u}{c}}$

Q24. A light beam is emitted at an angle θ_0 with respect to the x' -axis in S' frame which is moving with velocity $u\hat{i}$. Then the angle θ the beam makes with respect to x -axis in S' frame is

- (a) $\sin \theta = \frac{\sin \theta_0 \sqrt{1 - \frac{u^2}{c^2}}}{1 + \frac{u}{c} \cos \theta_0}$ (b) $\sin \theta = \frac{\sin \theta_0 \sqrt{1 - \frac{u^2}{c^2}}}{1 + \frac{u}{c} \sin \theta_0}$
 (c) $\sin \theta = \frac{\cos \theta_0 + \frac{u}{c}}{1 + \frac{u}{c} \cos \theta_0}$ (d) $\sin \theta = \frac{1 + \frac{u \cos \theta_0}{c}}{\cos \theta_0 + \frac{u}{c}}$

Q25. A light beam is emitted at an angle θ_0 with respect to the y' -axis in S' frame which is moving with velocity $u\hat{i}$. Then the angle θ the beam makes with respect to y -axis in S frame is

- (a) $\sin \theta = \frac{\sin \theta_0 \sqrt{1 - \frac{u^2}{c^2}}}{1 + \frac{u}{c} \cos \theta_0}$ (b) $\cos \theta = \frac{\cos \theta_0 \sqrt{1 - \frac{u^2}{c^2}}}{1 + \frac{u}{c} \sin \theta_0}$
 (c) $\sin \theta = \frac{\cos \theta_0 + \frac{u}{c}}{1 + \frac{u}{c} \cos \theta_0}$ (d) $\sin \theta = \frac{1 + \frac{u \cos \theta_0}{c}}{\cos \theta_0 + \frac{u}{c}}$

- Q26. A light beam is emitted at an angle θ_0 with respect to the x' -axis in S frame which is moving with velocity $u\hat{i}$. Then the angle θ the beam makes with respect to x -axis in S' frame is

$$(a) \tan \theta = \frac{\cos \theta_0 + \frac{v}{c}}{\sin \theta_0 \sqrt{1 - \frac{u^2}{c^2}}}$$

$$(b) \tan \theta = \frac{\sin \theta_0 + \frac{v}{c}}{\cos \theta_0 \sqrt{1 - \frac{u^2}{c^2}}}$$

$$(c) \tan \theta = \frac{\cos \theta_0 - \frac{v}{c}}{\sin \theta_0 \sqrt{1 - \frac{u^2}{c^2}}}$$

$$(d) \tan \theta = \frac{\sin \theta_0 - \frac{v}{c}}{\cos \theta_0 \sqrt{1 - \frac{u^2}{c^2}}}$$

- Q27. The frame S' is moving with respect to frame S with speed v in positive x direction. If a'_x is x component of acceleration of particle A with respect to S' frame then the acceleration of A with respect to frame S is given by

$$(a) a_x = \frac{a'_x \left(1 - \frac{v^2}{c^2}\right)^{1/2}}{1 + \frac{u'_x v}{c^2}}$$

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

$$(c) a_x = \frac{a'_x \left(1 - \frac{v^2}{c^2}\right)^{3/2}}{\left(1 + \frac{u'_x v}{c^2}\right)^2}$$

$$(d) a_x = \frac{a'_x \left(1 - \frac{v^2}{c^2}\right)^{3/2}}{\left(1 + \frac{u'_x v}{c^2}\right)^3}$$

- Q28. 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. The speed of the particle as seen from S is:

$$(a) \frac{c}{\sqrt{2}}$$

$$(b) \frac{c}{2}$$

$$(c) \frac{\sqrt{7}c}{4}$$

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

- Q29. 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 $0.6c$ 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

$$(a) 0.67c$$

$$(b) 0.81c$$

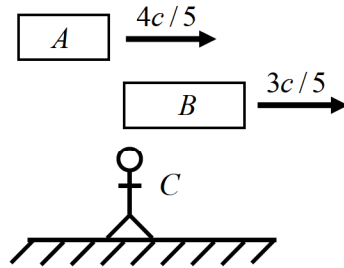
$$(c) 0.90c$$

$$(d) 0.46c$$

- Q30. 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 **opposite** 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) $0.46c$
- Q31. 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) $\cos \theta' = \frac{1}{2}$
- Q32. A circle of radius $5m$ lies at rest in x - y plane in the laboratory. For an observer moving with a uniform velocity v along the y direction, the circle appears to be an ellipse with an equation

$$\frac{x^2}{25} + \frac{y^2}{9} = 1$$
 The speed of the observer in terms of the velocity of light c is,
 (a) $\frac{9c}{25}$ (b) $\frac{3c}{5}$ (c) $\frac{4c}{5}$ (d) $\frac{16c}{25}$
- Q33. 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) $\left(1 - \frac{u^2}{c^2}\right)^{1/2}$ (b) $\left(1 - \frac{u^2}{c^2}\right)^{-1/2}$ (c) $\left(1 - \frac{u^2}{c^2}\right)$ (d) $\left(1 - \frac{u^2}{c^2}\right)^{-1}$
- Q34. It is found that pions are radioactive and their half life is measured to be 1.77×10^{-8} sec. A collimated pion beam, leaving the accelerator target at speed of $0.99c$, then pion is found to drop to half of its original intensity at a distance of
 (a) $5.25m$ (b) $3.9m$ (c) $52.5m$ (d) $39m$
- Q35. Two spaceships A and B are moving with speed $0.6c$ with respect to earth. Both the spaceships are moving in opposite directions. Space ship A emits light which will appear one year after to an observer attached to the earth. Same light pulse will appear to an observer attached to space ship B after a time
 (a) 0.8 year (b) 1 year (c) 1.7 years (d) 2.12 years

- Q36. It is found that pions are radioactive. The half life of the pions in their rest frame is measured to be 1.77×10^{-8} sec. A collimated pion beam leaves the accelerator target at speed of $0.99c$, then the distance travelled by pions when its intensity became half is equal to
- (a) $5m$ (b) $10m$ (c) $39m$ (d) $78m$
- Q37. Two trains, A and B , each have proper length L and move in the same direction. A 's speed is $4c/5$, and B 's speed is $3c/5$. A starts behind B (see Figure).



As viewed by person on A , how long does it take for A to overtake B ?

- (a) $\frac{5L}{c}$ (b) $\frac{7L}{c}$ (c) $\frac{L}{5c}$ (d) $\frac{L}{7c}$