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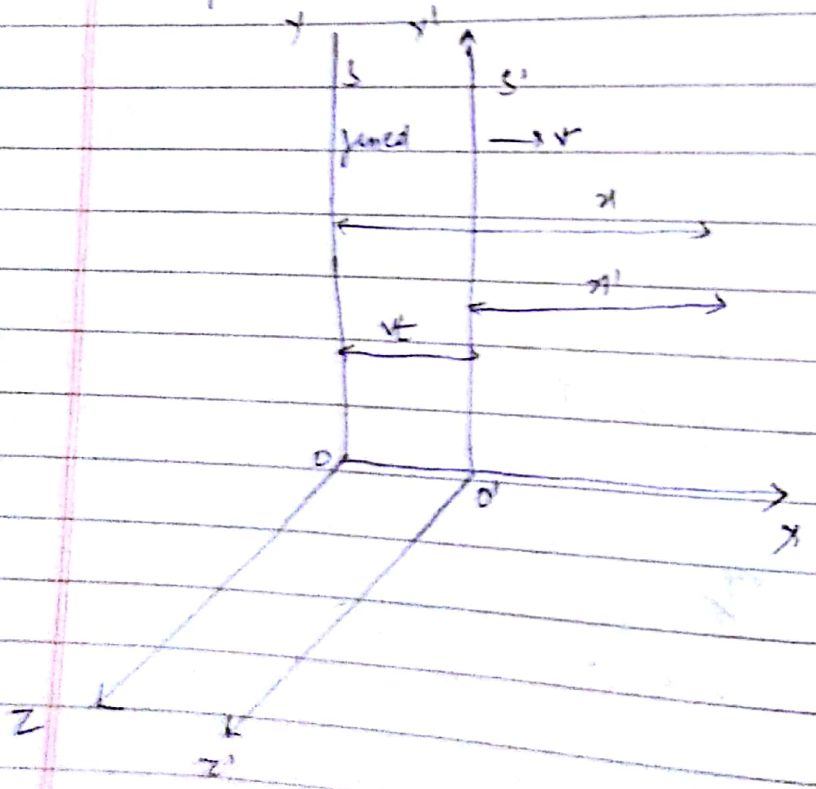
PHYSICS

MOD 3 Quantum Physics

- Black body Radiation
- Photoelectric effect
- Compton effect
- Pair production
- De Broglie Hypothesis
- Heisenberg Uncertainity Principle
- X ray production

Data transformation from one inertial frame to an
(velocity, time)



Let an event at a point P whose co-ordinates P (x, y, z, t) and S (x', y', z', t') as observed measured from S and S' respectively.

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When S is fixed

$x' = x - vt$

$y' = y$

$z' = z$

$t' = t$

When S' is fixed

$x = x' + vt'$

u'_x = x component velocity of a particle when measured from S' frame

$$u'_x = \frac{dx'}{dt} = \frac{d}{dt}(x - vt)$$

$$= \frac{dx}{dt} - v$$

$$u_x' = u_x - v$$

$$u_y' = \frac{dy'}{dt} = \frac{dy}{dt} = u_y$$

$$u_z' = u_z$$

$\boxed{u' = u - v}$ Galilean transformation.

train A ⟶ 80 km/hr → N
B ⟶ 70 km/hr → N
C ⟶ 60 km/hr → S

$u = 80$

$u' = ??$

$v = 70$

$u' = u - v$

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$a'_x = \frac{d v'_x}{dt} = \frac{d}{dt}(v_x - v)$

$= \frac{d v_x}{dt} = a_x$

$a'_x = a_x$

$m a'_x = m a_x$

$F'_x = F_x$

#

① $\xrightarrow[0.85c]{e^-}$ $\xleftarrow[0.8]{e^-}$ c = speed of light $= 3 \times 10^8$ m/s

$v' = ??$

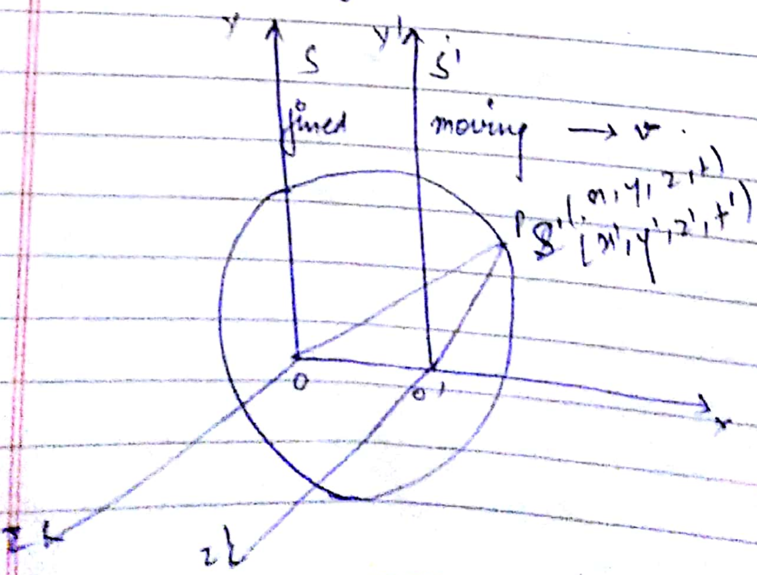
$v = 0.85c$

$v = -0.8c$

$v' = 1.65c$ ✗

② $\xrightarrow[c]{\text{Photon}}$ $\xleftarrow[c]{\text{Photon}}$ $v' = 2c$ ✗ → not possible

Lorentz transformation



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Let a pulse of light be generated at $t = 0$ at origin ~~and~~ which grows in space

After a time the pulse reaches at $P(x, y, z, t)$ & (x', y', z', t')

(1) S frame

$$c = \frac{\sqrt{x^2 + y^2 + z^2}}{t}$$

$$x^2 + y^2 + z^2 - c^2 t^2 = 0$$

(2) S' frame

$$c = \frac{\sqrt{x'^2 + y'^2 + z'^2}}{t'}$$

$$x'^2 + y'^2 + z'^2 - c^2 t'^2 = 0$$

$$x^2 + y^2 + z^2 - c^2 t^2 = x'^2 + y'^2 + z'^2 - c^2 t'^2$$

$y' = y$ $\longrightarrow$ bcoz we consider motion only along x axis

$z' = z$.

$$x^2 - c^2 t^2 = x'^2 - c^2 t'^2 \quad \text{--- (3)}$$

$t = t'$

$x = x'$ ✗

c is independent of speed of source and observer.

Lorentz introduced

$$x' = \gamma (x - vt) \quad \text{--- (4)}$$

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and

$$x = \gamma'(x' + vt') \quad - (5)$$

Put value of x' in (3) from (iv)
~~t'~~ from (5)
~~x' from~~ .

Comparing coeff of x^2 & t^2

finally we get $\gamma = \gamma' = \dfrac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \text{and} \quad t' = \frac{t - vx/c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

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$$u_x' = \frac{dx'}{dt'} = \frac{dx - vdt}{dt - \frac{vdx}{c^2}} = \frac{\frac{dx}{dt} - v}{1 - \frac{v}{c^2}\frac{dx}{dt}}$$

$$u_x' = \frac{u_x - v}{1 - \frac{v \cdot u_x}{c^2}}$$

$$\therefore u' = \frac{u - v}{1 - \frac{v}{c^2}u} \qquad u = \frac{u' + v}{1 + u'\frac{v}{c^2}}$$

Q) (1) $\xrightarrow{c}$ $\xleftarrow{c}$ (2)

rel v b/w them

$u' = ?$ $u = c$ $v = -c$

$$u' = \frac{c - (-c)}{1 + \frac{c^2}{c^2}} = \frac{2c}{2} = c$$

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e^- $\xrightarrow{\quad}$ $\xleftarrow{\quad}$ e^-

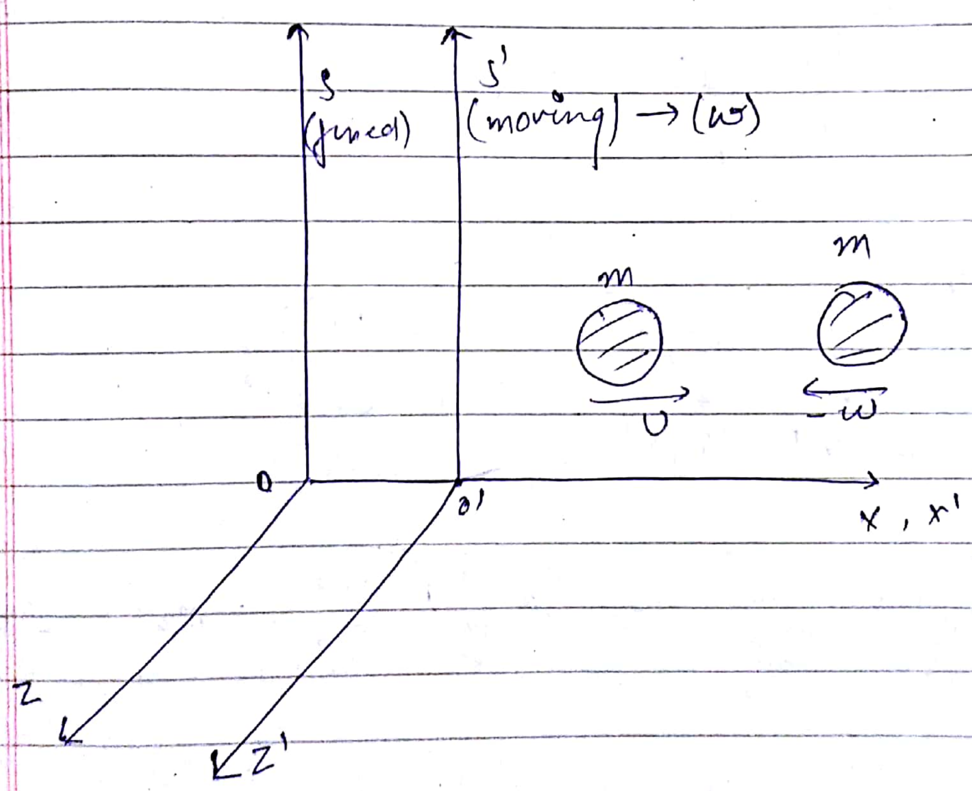
$0.9c$ $0.8c$

$$v' = \frac{0.9c + 0.8c}{1 + 0.9 \times 0.8} = \frac{1.7c}{1 + 0.72} = \frac{1.7c}{1.72}$$

$$\approx c.$$

Mass Variation with velocity.

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$



$v \rightarrow$ velocity of particle with mass m.

Let two exactly similar ball of mass m are approaching to each other with velocity v and −v respectively in S' frame. After collision they aqualised to a single body of mass 2m' when observed from S' frame

$$m(v) + m(-v) = 2m' \times V \quad (V = 0)$$

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When observed from S frame. Let $m_1 v_1$ & $m_2 v_2$ be the mass & velocity of 2 body respectively

$$v_1 = \frac{v + w}{1 + \frac{vw}{c^2}} \qquad v_2 = \frac{-v + w}{1 - \frac{vw}{c^2}}$$

from Momentum Conservation.

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) w$$

$$m_1 (v_1 - w) = m_2 (w - v_2)$$

$$m_1 \left[\frac{v + w - w - vw^2/c^2}{1 + \frac{vw}{c^2}} \right] = m_2 \left[\frac{w - \frac{vw^2}{c^2} + v - w}{1 - \frac{vw}{c^2}} \right]$$

$$\frac{m_1}{m_2} = \frac{1 + vw/c^2}{1 - vw/c^2}$$

again,

$$HM = \frac{\sqrt{1 - v_2^2/c^2}}{\sqrt{1 - v_1^2/c^2}} = \frac{1 + vw/c^2}{1 - vw/c^2}$$

$$m_1 \sqrt{1 - \frac{v_1^2}{c^2}} = m_2 \sqrt{1 - \frac{v_2^2}{c^2}} = m_3 \sqrt{1 - \frac{v_3^2}{c^2}}$$

$$= m \sqrt{1 - \frac{v^2}{c^2}} = m_0 \sqrt{1 - \frac{v^2}{c^2}}$$

$$m \sqrt{1 - \frac{v^2}{c^2}} = m_0$$

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}} \qquad \text{if } v << c \quad m = m_0$$

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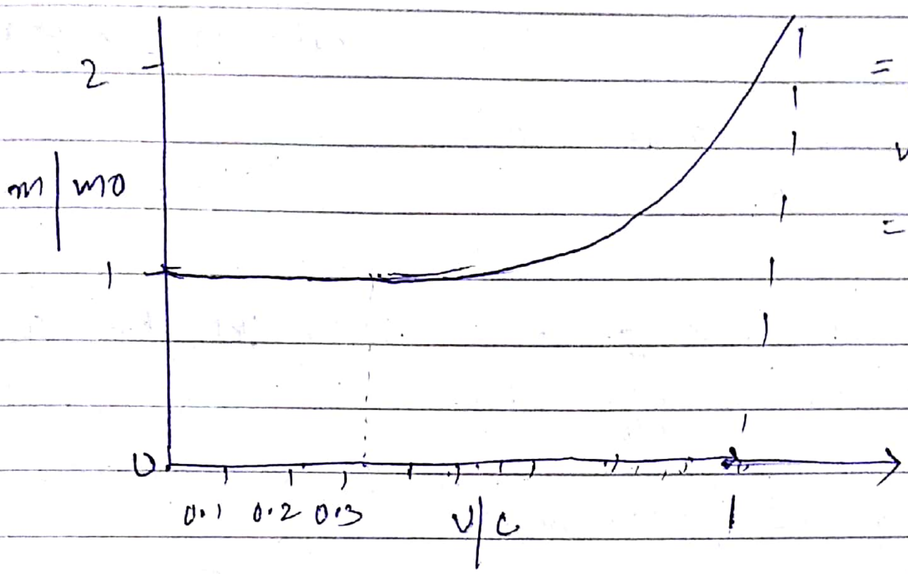
if $v \to c$, $\sqrt{1-\frac{v^2}{c^2}} < 1$ $m_1 > m_2$

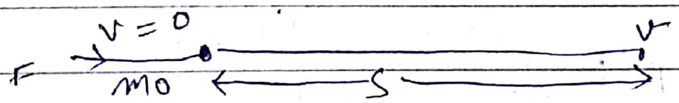
if $v = c$, $m = \infty$ ✗

if $v > c$, $m =$ imaginary.



$v = 0.3c$
$= 9 \times 10^7$ m/s
$v = 0.4c$
$= 1.2 \times 10^8$ m/s

Einstein's mass energy Relation ($E = mc^2$)



$$W = \int_0^s \vec{F} \cdot \vec{ds} = \int F \cdot ds = \int \frac{d(mv)}{dt} \cdot ds$$

$$= \int v \cdot d(mv) = \int v\,[m\,dv + v\,dm] \quad \text{— (1)}$$

again, $m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$

$m^2c^2 - m^2v^2 = m_0^2c^2$

$2mc^2\,dm - 2mv^2\,dm - 2vm^2\,dv = 0$

$c^2\,dm = v^2\,dm + mv\,dv$ — (2)

from eqn (1) & (2) work done acting on body

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$$W = \int_{m_0}^{m} c^2\, dm$$

$$K.E = c^2[m - m_0]$$
$$mc^2 - m_0c^2$$
└→ rest mass energy.

$$K.E + m_0c^2 = mc^2$$
$$T.E = E = mc^2$$

* Show that for a low speed rel. KE reduces to its classical energy value.

$$\text{rel. KE} = mc^2 - m_0c^2$$
$$= \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} \cdot c^2 - m_0c^2$$
$$= m_0c^2\left[\left(1-\frac{v^2}{c^2}\right)^{-1/2} - 1\right]$$
$$= m_0c^2\left[1 + \frac{1}{2}\frac{v^2}{c^2} - 1\right]$$

non rel. KE

$$= \frac{m_0v^2}{2}$$