

Einstein's hypotheses:

1. The laws of nature are equally valid in every inertial reference frame.

2. The speed of light in empty space is same for all inertial observers, regardless of their velocity or the velocity of the source of light.



Moving clocks run slow

Moving objects appear shorter

Moving object's mass increases

GPS system



3 m precision requires corrections for relativity



Increase in $m = (\gamma - 1)m_0$

γ**-1** =??





Below v/c = 0.5, "other stuff" is not so large



Below v/c = 0.1, "other stuff" is negligible





Below v/c = 0.1,
$$\gamma = 1 + \frac{1}{2} \frac{v^2}{c^2}$$

 $\gamma - 1 = \frac{1}{2} \frac{v^2}{c^2}$

This covers all velocities ever encountered by mankind in 1905

Increase in mass = $(\gamma - 1)m_0$ for v<0.1c = $\gamma - 1 = \frac{1}{2} \frac{v^2}{c^2}$ increase in mass = $\frac{1}{2} m_0 \frac{v^2}{r^2}$ Multiply both sides by c^2 (increase in mass) $c^2 = \frac{1}{2} m_0 v^2$ **Kinetic energy**

For v < 0.1c $m = m_0 + increase in m$ Multiply both sides by c^2 $mc^2 = m_0c^2 + (increase in m)c^2$ $mc^2 = m_0c^2 + kinetic energy$

Einstein's hypothesis:

Kinetic energy = (m - m₀)c² =
$$\frac{1}{2}$$
 m₀v² + "other
stuff"

Since this is only significant for huge speeds, Newton, etc had no way of knowing about it



Mass is a form of energy



The conversion factor

Energy (Joules) = Mass (kg) \times (3 \times 10⁸)² $=9 \times 10^{16}$

 $E(Joules) = 90,000,000,000,000 \times m(kg)$



Electric power usage on Oahu Power =1,300 MegaWatts = $1,300 \times 10^6$ Watts Power = $1.3 \times 10^9 \text{ J/s}$ Energy usage = Power x time # of secs in 1 yr Energy usage/yr = 1.3×10^9 J/s x (3.2×10^7 s/yr) $=1.3 \times 3.2 \times 10^{9+7} \text{ J/yr}$ $=4.2 \times 10^{16} \text{ J/yr}$

How much mass would be needed to produce 4.2 x 10¹⁶ J ?

$$E = mc^2 \rightarrow m = \frac{E}{c^2}$$

$$m = \frac{4.2 \times 10^{16} \text{ J}}{9 \times 10^{16} \text{ m}^2/\text{s}^2}$$

$$m = \frac{4.2}{9} \text{ kg}$$

$$m = 0.47 \text{ kg}$$

Nuclear Power Plant



Another nuclear power plant

Sun's power output=4x10²⁶Watts



Sun converts mass to energy Power = energy generated in one sec:

$$E_{1sec} = 4 \times 10^{26} J = m_{1sec} C^2$$

$$m_{1sec} = \frac{E_{1sec}}{C^2} = \frac{4 \times 10^{26} \text{J}}{9 \times 10^{16} \text{m}^2/\text{s}^2}$$

$$m_{1sec} = 4/9 \times 10^{26-16} \text{ kg} = 0.44 \times 10^{10} \text{ kg}$$

