

Physics 12 Relativity Review

Test includes
- river problem (2)
- gen relativity (3 units)
/25

Name: Key

Formula:

t_o, L_o, m_o : These are the variables that are measured when the observer is at rest with respect to the measurement being made.

$$t = \frac{t_o}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$L = L_o \sqrt{1 - \frac{v^2}{c^2}}$$

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

$$u = \frac{v + u'}{1 + \frac{vu'}{c^2}}$$

$$t > t_o \quad \text{ship time}$$

$$L < L_o \quad \text{normal}$$

$$m > m_o \quad \text{normal}$$

$$E = mc^2 \quad E_k = \frac{1}{2}mv^2$$

Questions:

1. If you were travelling away from the Earth at $0.5c$, would you notice a change in your heartbeat? Would your mass, height, or waistline change? What would observers on Earth, using a telescope to see you, say about you?

- you would not notice a change.
- A stationary observer would see you slow down, your mass increase and you shrink in direction of motion.

2. What happens to the relativistic factor $\sqrt{1 - \frac{v^2}{c^2}}$ when objects travel at normal, everyday velocities?

$$\sqrt{1 - \frac{30 \text{ m/s}}{3 \times 10^8 \text{ m/s}}^2} = \sqrt{1} = 1$$

3. A spaceship travels at $0.99c$ for 3.0 years ship time. How much time would pass on the Earth?

$$t = \frac{t_o}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{3 \text{ yrs}}{\sqrt{1 - (0.99)^2}} = 21 \text{ yrs}$$

4. A spaceship has been gone from the Earth for a total time of 5.0 years ship time. The people on the Earth have measured the time that the ship was away to be 25 years. How fast was the ship travelling?

$$\sqrt{1 - \frac{v^2}{c^2}} = \frac{t_o}{t}$$

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

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

$$v^2 = c^2 \left(1 - \frac{t_o^2}{t^2}\right)$$

$$v = \sqrt{c^2 \left(1 - \frac{t_o^2}{t^2}\right)}$$

$$= \sqrt{c^2 \left(1 - \left(\frac{5}{25}\right)^2\right)} = 2.9 \times 10^8 \text{ m/s} = 0.98c$$

5. A 520m long (measured when it was stationary) spaceship passes by the Earth at 0.87c. What length would the people on Earth say the spaceship is?

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}} = 520 \text{m} \sqrt{1 - \left(\frac{0.87}{1}\right)^2} = 256 \text{m} = \underline{2.6 \times 10^2 \text{m}}$$

6. A 25kg rock is accelerated to a speed of 0.98c.
a. What would the mass of this rock be at this speed?

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{25 \text{kg}}{\sqrt{1 - \left(\frac{0.98}{1}\right)^2}} = 125.6 \text{kg} \rightarrow \underline{1.3 \times 10^2 \text{kg}}$$

if the rock converted into

- b. How much energy would be associated with the rock at rest? At this speed?

at rest: $E = mc^2 = 25 \text{kg} c^2 = 2.25 \times 10^{18} \text{J} = \underline{2.3 \times 10^{18} \text{J}}$

at 0.98c: $E = mc^2 = (125.6) c^2 = \underline{1.1 \times 10^{19} \text{J}}$

7. An observer on Earth sees an enemy alien spaceship approaching at 0.60c. The Starship Enterprise comes to the rescue overtaking the spaceship at 0.90c relative to the alien spaceship. How fast would the observers on Earth measure the Enterprise to be travelling at?

$$u = \frac{v + u'}{1 + \frac{vu'}{c^2}} = \frac{0.6c + 0.9c}{1 + \frac{(0.6)(0.9)}{1}} = \underline{0.97c} \text{ (toward } \oplus \text{)}$$

Review Answers:

- You would not notice anything different about yourself. To you everything seems normal. To a stationary observer your heartbeat and other life signs would all have slowed down compared to those on Earth. Your mass would have increased and you would be skinnier in the direction of motion.
- Relativistic factor becomes equal to 1! This means that at ordinary speeds we do not worry about it.
- 21 years ✓
- 0.97c ✓ or $2.94 \times 10^8 \text{m/s}$ ✓
- 256m $2.6 \times 10^2 \text{m}$ ✓
- a. 125kg b. $2.25 \times 10^{18} \text{J}$, $1.1 \times 10^{19} \text{J}$ ✓
- 0.97c ✓

or $2.94 \times 10^8 \text{m/s}$ ✓
1.3 × 10² kg ✓
[toward ⊕] ✓