

# Mass and Energy

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The speed limit for the universe is the speed of light.

Mathematical reason:  $\sqrt{1 - \frac{v^2}{c^2}}$  ←

Not a physical reason.  
Not good enough.

if  $v > c$  then we'd have the root of a negative number. ☹

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When going fast your mass increases.

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

This makes a "speed limit" because as  $v$  gets close to  $c$ , mass begins to approach infinity.

To move you need to have energy:

$$KE = \frac{1}{2} m v^2$$

↑ approaches infinity.

↑ Big getting close to infinity

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Dan has a mass of 78kg. He gets shot out of a cannon at  $0.7c$ .

What is his relativistic mass to a fixed wall?

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{78}{\sqrt{1 - \frac{(0.7c)^2}{c^2}}} = \frac{78}{\sqrt{1 - 0.49}} = \frac{78}{\sqrt{0.51}} = 109.2 \text{ kg}$$

a) How much energy does he impart to the wall when he collides with it?

$$\begin{aligned} KE &= \frac{1}{2} mv^2 = \frac{1}{2} (109.2 \text{ kg}) (0.7 \times 3 \times 10^8)^2 \\ &= \frac{1}{2} \times 109.2 \text{ kg} \times 13.23 \times 10^{16} \\ &= 722.4 \times 10^{16} = \boxed{7.224 \times 10^{18} \text{ J}} \end{aligned}$$

## Rest Mass Energy

We've seen that objects in motion increase their mass,

Objects in motion increase their energy.

Motion seems to impart extra mass which can be described as extra energy.

## Mass-Energy Equivalence

Mass and energy are equivalent and can be

transformed from one form into another.

This updates a key physical law!

## Law of Conservation of Mass and Energy

Mass and energy can neither be created nor destroyed, but simply transformed from one form to another.

What is the inherent energy of an object at rest?

↑ called the Rest Mass Energy

$$E = mc^2$$

This means for 1g.

$$E = 0.001 \cdot (3 \times 10^8)^2$$

$9 \times 10^{16}$

$$E = 9 \times 10^{13} \text{ J}$$

$$1 \text{ km} = 1 \times 10^3 \text{ m}$$

$$g \approx 10$$

Enough energy to lift something  
 $9 \times 10^9 \text{ kg}$

9,000,000,000 kg

1 km