Universal Specificity Investigation 4: Relativistic Specific Energy Model

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Prior investigations into the theory of universal specificity found a proper conception of time missed in common practice; which led to the realization that a universally stationary frame (USF) must exist; which led to the discovery that the average effective speed of light, c_0, is identical in all directions for any inertial reference frame, and is a function of that frame's velocity, v, relative to the USF, as shown in Equation (1); which finally led to discovering the cause of kinetic time dilation to be a change in specific kinetic energy.

$$c_0 = c\sqrt{1-\frac{v^2}{c^2}} = \frac{1}{\gamma}c \tag{1}$$

This last investigation ended with the realization that Newtonian specific kinetic energy model relates cleanly to changes in ITD, as shown in Equation (2); however, it remains to be seen if this model is the same as the relativistic specific kinetic energy model. That is the focus of the investigation in this paper.

$$\begin{aligned}\frac{dt'}{dt} &= \sqrt{1-\frac{v^2}{c^2}} = \sqrt{1-\frac{2\Delta e_K}{c^2}} \\ &= \sqrt{1-\frac{2\int a(r)dr}{c^2}} = \sqrt{1-\frac{2w}{c^2}}\ \blacksquare\end{aligned} \tag{2}$$

1. Relativistic Specific Kinetic Energy

Relativistic kinetic energy was first introduced in a thought experiment devised by Einstein, by which he derived a relationship between the mass and internal energy of an object.

In this thought experiment, Einstein considered an object at rest that emits energy, in the form of radiation, in two opposite directions, but in equal amounts. Then he considered this same object with the same emission, but viewed from a different inertial reference frame that is moving relative to the object along some arbitrary axis. Figure 1 depicts this thought experiment [1].

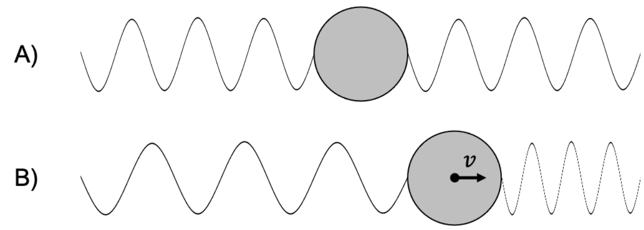

Figure 1. A) Object's inertial reference frame; B) Inertial reference frame with relative motion.

Before relating energy lost to mass lost, Einstein first compared the total energies measured by the two reference frames. He let E represents the total energy of the object as measured from the object's inertial reference frame, and H represents the total energy of the object as measured from the reference frame with relative motion. Einstein said, "[t]hus it is clear that the difference $H - E$ can differ from the kinetic energy [ΔE_K] of the body, with respect to the other [reference frame with relative motion], only by an additive constant C..." The resulting model is: $H - E = \Delta E_K + C$ [1].

What is the total energy model and kinetic energy model used by Einstein, and upon what do these models depend? The answer to the first part of the question is best expressed by Feynman in his famous lectures. In short, Feynman derives the total energy relation to kinetic energy from the relativistic mass model that conserves momentum [2], as shown in Equation (3).

$$\begin{aligned} m &= \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} = m_0\left(1-\frac{v^2}{c^2}\right)^{-1/2} \\ m &= m_0\left(1+\frac{1}{2}\frac{v^2}{c^2}+\frac{3}{8}\frac{v^4}{c^4}+\dots\right) \\ m &\approx m_0 + \frac{1}{2}m_0\frac{v^2}{c^2} \\ mc^2 &\approx m_0c^2 + \frac{1}{2}m_0v^2\ \blacksquare \end{aligned} \tag{3}$$

According to this model, the total energy, mc^2, is the internal energy, m_0c^2, plus the kinetic energy. This result relates to $H - E = \Delta E_K + C$ as follows:

$$H = mc^2 \tag{4a}$$
$$E = m_0c^2 \tag{4b}$$
$$\Delta E_K = H - E = mc^2 - m_0c^2 \tag{4c}$$
$$\therefore\ C = 0 \text{ in this case} \tag{4d}$$

To now answer the second part of the earlier question, these models ultimately depend the relativistic mass model representing the inertia of an object. To see this dependency, one can derive this kinetic energy model in Equation (4c) from Newtonian first principles, as shown in some detail in Equation (5).[2]

$$
\begin{aligned}
&\text{Let} : \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \\
&m\gamma^{-1} = m_0 = \text{invariant}
\end{aligned}
$$

$$
\begin{aligned}
\Delta E_K &= \int F(s)ds \\
\Delta E_K &= \int \frac{dp}{dt}ds \\
\Delta E_K &= \int vd(mv) \\
\Delta E_K &= \int vd(\gamma m_0 v) = m_0 \int vd(\gamma v) \\
\Delta E_K &= m_0(\gamma-1)c^2 = mc^2 - m_0c^2 \blacksquare
\end{aligned} \tag{5}
$$

Converting Equation (5) into specific kinetic energy is not as simple as factoring out m_0. What makes this fact challenging to see is that mass is an overused term since, depending on context, it represents inertia and quantity of matter. *Inertia* is an object's resistance to a change in motion, and it is simultaneously a function of an object's quantity of matter and how responsive an object is to an unbalanced force. When mass represents inertia, therefore, as it seems to in relativistic mass, it combines two fundamentally different quantities: (1) the quantity of matter comprising an object, which has been traditionally thought of as mass; and (2) how responsive an object is to an unbalanced force, which is ignored in Newtonian mechanics.

This leads to a proper understanding of the problem with simply factoring out m_0. Specific energy is defined as energy divided by its inertia. m_0 rightly represents the quantity of matter, i.e., the object's responsiveness to an unbalanced force can be ignored. The quantities remaining, therefore, once m_0 is factored out of Equation (4c) are: (1) specific kinetic energy; and (2) the object's responsiveness to an unbalanced force.

How does one factor out the contribution of the object's responsiveness to an unbalanced force? The answer is rather simple: remove the inertia from the start, and its influence on energy are removed too, thus, only specific energy remains. As in, remove inertia from momentum, and derive specific kinetic energy from the integration of specific force over some change in distance, as shown in Equation (6).

$$
\begin{aligned}
\Delta e_K &= \int f(s)ds \\
\Delta e_K &= \int \frac{d(\frac{p}{m})}{dt}ds \\
\Delta e_K &= \int vdv = \frac{1}{2}v^2 \blacksquare
\end{aligned} \tag{6}
$$

In other words, relativistic specific kinetic energy is also the Newtonian specific kinetic energy.

[2]The full derivation is presented here [3].

2. Total Specific Energy Model

The analysis leading to Equation (6) implies that simply factoring out m_0 from internal energy, in Equation (4b), is also not sufficient to derive specific internal energy, since contributions of inertia in the remaining quantity would necessarily remain. A slight modification to Feynman's method of deriving the total energy equation can be used to derive the total specific energy equation, which includes the specific internal energy component, as shown in Equation (7).

$$
\begin{aligned}
m &= \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma_K m_0 \\
m^2\left(1-\frac{v^2}{c^2}\right) &= m_0^2 \\
m^2 &= m_0^2 + m^2\frac{v^2}{c^2} \\
c^2 &= \frac{m_0^2}{m^2}c^2 + v^2 \\
\frac{1}{2}c^2 &= \gamma_K^{-2}\frac{1}{2}c^2 + \frac{1}{2}v^2 \\
e_T &= e_I + \Delta e_K \blacksquare
\end{aligned} \tag{7}
$$

According to this model, the total specific energy, $\frac{1}{2}c^2$, is the specific internal energy, $\gamma_K^{-2}\frac{1}{2}c^2$, plus the specific kinetic energy, $\frac{1}{2}v^2$. This is akin Einstein's total energy model where total energy is internal plus kinetic energy. Unlike Einstein's model, however, the specific internal energy of an object diminishes as it gains specific kinetic energy, all the while its total specific energy is conserved. The reason internal energy remains constant in Einstein's model is due to

One way to interpret these findings is when an object is at rest, then all of its specific energy is internal (the inner happenings are all that is happening). However, if an object achieves c, then all of its specific energy is in its motion (there is no inner happenings because the duration for any internal change becomes infinite). At either extreme, or any point in between, the object's total specific energy is conserved.

It has been said that the maximum speed that can link two events causally (as in event A affects event B) is the speed of light [4]—specificity accepts this notion. Now, if the internal energy term truthfully represents the internal happenings for an object in a given reference frame, then this term is actually dependent on c_0, since c_0 is the maximum speed that internal happenings can occur. Indeed if we keep in mind the relationship between c_0 and c, shown in Equation (1), while reviewing the specific internal energy term in Equation (7), then we see that c_0 was there all along, as shown in Equation (8).

$$
\begin{aligned}
\frac{1}{2}c^2 &= \frac{1}{2}c_0^2 + \frac{1}{2}v^2 \\
e_T &= e_I + \Delta e_K
\end{aligned} \tag{8}
$$

e_I being dependent on c_0, creates a new perspective on the kinship between e_I and e_T. Since e_T is limited by the speed of light in the USF, just as e_I is limited by the average effective speed of light in the moving frame. In this way, therefore, e_I can be thought of as total specific rest energy. Indeed, when an object's velocity relative to the USF becomes zero, the average effective speed of light *is* c for that object's frame, and therefore, $e_I = e_T$.

Integrating this discovery back into Equation (2), we discover a new implication, which is c^2 is really twice total specific energy, e_T, as shown in Equation (9).

$$\frac{dt'}{dt} = \sqrt{1 - \frac{2\Delta e_K}{c^2}} = \sqrt{1 - \frac{\Delta e_K}{e_T}} = \sqrt{1 - \frac{\int a(r)dr}{e_T}} = \sqrt{1 - \frac{w}{e_T}} \blacksquare \tag{9}$$

This means time dilation is really a function of the ratio, Δe_K to e_T. Additionally, this also means the average effective speed of light (normalized by c) is a function of this same ratio, as shown in Equation (10).

$$\frac{c_0}{c} = \sqrt{1 - \frac{\Delta e_K}{e_T}} \tag{10}$$

This suggests that time dilation is actually a consequence of a reduction in c_0, as shown in Equation (11)—effectively making the average effective speed of light the metronome of the Universe.

$$\frac{dt'}{dt} = \frac{c_0}{c} \tag{11}$$

The causal chain then is this: specific work done (in the USF), which is the prime cause, causes an object's velocity in the USF to increase; an increase in this velocity causes a reduction in c_0 in the object's frame; and finally, a reduction in c_0 causes the interval over which all change occurs in the object's frame to increase. Specific work done can still properly be said to cause kinetic time dilation, but only because of all the intermediary (and simultaneous) steps in between the primary cause and the final effect.

3. Ambiguity Relating to Total Energy

Several sticking points remain, when relating total specific energy to total energy, which will have to wait to be resolved in a later investigation since the current set of conceptual tools is insufficient to address it now. One such sticking point is it seems inertia's contribution to total energy, I_E, is $2m$, as shown in Equation (12).

$$E_T = mc^2 = I_E e_T = I_E \frac{1}{2} c^2 \quad \therefore\ I_E = 2m \tag{12}$$

I_E might be $2m$, as Equation (12) suggests, which could be an odd manifestation of integrating a change in momentum rather than specific momentum over some distance. However, something else might be amiss too, which has not been fully investigated either—such as the possibility that a miscalibration of instruments leads to the appearance that $E = mc^2$. For example, suppose a calibrated E_T was really $\frac{1}{2}mc^2$ instead, then I_E would be m. I_E being m arguably makes more sense than inertia contributing twice to the total energy compared to what it contributes to momentum.

Any further investigation into this question, however, will have to be tabled until more conceptual tools are developed. Regardless of the current ambiguity on the matter, this much remains clear, our instrument readings (miscalibrated or not) are consistent with $E = mc^2$ [5].

4. Conclusion

In conclusion, this investigation found that the relativistic specific kinetic energy model is the Newtonian model, which resulted in a total specific energy model's relation to specific internal and specific kinetic energy. Additionally, this investigation found a deeper understanding into the nature of specific internal energy, in that it is analogous to total specific rest energy. This new total specific energy model relates to the ITD equation, where the velocity ratio v^2 to c^2 is really an specific energy ratio, Δe_K to e_T.

Ambiguity remains in how to properly relate total specific energy to total energy, but addressing them will have to wait for a later investigation, after more conceptual tools have been developed.

In the mean time, the next investigation will look into the question: if a change in specific kinetic energy of an object causes its time differential to change, then what happens to an object that exists in a time dilation gradient, such as those gradients that exist around massed objects?

References

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