# Universal Specificity Investigation 7: Relating Specific Energy to Energy

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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 when normalized by $c$ it is a function of specific work done in the USF, as shown in Equation (1); which eventually led to discovering the cause of total time dilation, shown Equation (2); which finally led to a total specific energy model complete with specific internal energy, specific kinetic energy and specific potential energy terms, shown in Equation (3).

$$\frac{c_0}{c} = \sqrt{1 - \frac{w}{e_T}} \tag{1}$$

$$\begin{aligned} \frac{dt'}{dt} &= \frac{c_0}{c} = \sqrt{1 - \frac{w}{e_T}} \\ &= \sqrt{1 - \frac{\Delta e_t}{e_T}} = \sqrt{1 - \frac{\Delta e_K + \Delta e_P}{e_T}} \end{aligned} \tag{2}$$

$$\begin{aligned} e_T &= e_I + \Delta e_K + \Delta e_P \\ \frac{1}{2}c^2 &= \frac{1}{2}c_0^2 + \frac{1}{2}v^2 + \int g(r)dr \end{aligned} \tag{3}$$

Some ambiguity remained during earlier investigations as to how to relate the specific energy model in Equation (3) to the relativistic energy model, shown in Equation (4).

$$\begin{aligned} \gamma_K &= \frac{1}{\sqrt{1 - \frac{\Delta e_K}{e_T}}} \\ E_T &= E_I + \Delta E_K \\ &= m_0c^2 + (\gamma_K - 1)m_0c^2 = m\gamma_K c^2 \end{aligned} \tag{4}$$

This relation only becomes more ambiguous since the total energy model lacks a potential energy term while the total specific energy model does not.

The focus of this investigation is to address how to properly relate specific energy to energy. The first order of business is to do a simple comparison, ignoring gravity. Then, retrace Einstein's derived relation of mass to energy, but include gravity. Lastly, a complete comparison between specific energy and energy will wrap up this investigation.

## 1. Simple Comparison

The *energy* of an object is defined as its ability to do work. The change in kinetic energy of an object, in the context where the Work-Energy Theory holds, is quantified by the amount of work put into an object, which is given by Equation (5).

$$E_K = \int F ds \tag{5}$$

Newton's second law gives the definition of force as the rate change of momentum, given in Equation (6), where *momentum* is loosely defined as an object's quantity of inertial motion.

$$F = \frac{dp}{dt} \tag{6}$$

Momentum, is comprised of two main components: inertia, and motion. *Inertia* is an object's resistance to a change in motion, and the motion is its velocity[2]. Relativistic momentum, which grantees conservation of momentum, is given in Equation (7), where $m_0$ is rest mass of an object (taken to be its quantity of matter), and $\gamma$ is given in Equation (8) [1]. The inertia component of momentum is taken to be $m_0\gamma$, and the motion component is taken to be $v$.

$$p = m_0\gamma v \tag{7}$$

$$\gamma = \frac{1}{1 - \frac{v^2}{c^2}} \tag{8}$$

Since motion and inertia are components of momentum, then each contributes to kinetic energy. Also, since each component is simultaneously in Equation (5), then parsing out the contributions of each to kinetic energy is rather messy.

As one simplification, energy might be thought of as the product of specific energy (non-inertia part) and the rest (interpreted as the inertia generated part). In this way total specific energy, ignoring gravity (which will be taken into consideration shortly), can be related to total energy, as shown in Equation (9), where $I$ represents the inertia component of energy:

[2] If we are being precise velocity in terms of fraction of the speed of light, which slows down in a gravitational field.

$$
\begin{aligned}
E_T = I_T e_T &= E_I + E_k \\
&= I_I e_I + I_K \Delta e_k + 0 \\
I_T &= 2\gamma_K m_0 \\
I_I &= 2\gamma_K^2 m_0 \\
I_K &= 2(\gamma_K - 1)\frac{c^2}{v^2} m_0 \\
&= 2\frac{\gamma_K - 1}{1 - \gamma_K^{-2}} m_0
\end{aligned} \tag{9}
$$

Next we consider the effects of gravity to total energy.

## 2. Factoring in Gravity

The total energy equation, which ignored gravity, is derived from a thought experiment devised by Einstein [2]. We will now modify this thought experiment to consider total energy in the context of gravity, where gravity contributes as a force rather than spacetime curvature.

In the original thought experiment, Einstein considered an object at rest that emits energy, in the form of radiation, in two opposite directions at some angle $\phi$, but in equal amounts equal to $\frac{1}{2}L$. 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 a simplified view of this thought experiment [2].

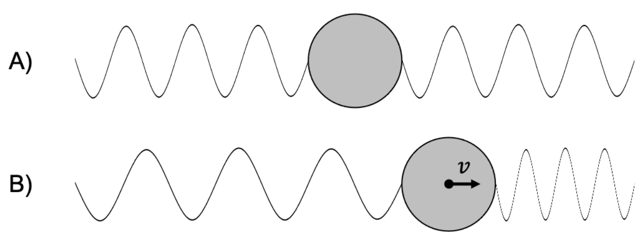


**Figure 1. A) Object's inertial reference frame; B) Inertial reference frame with relative motion.**

*A Simple Thought Experiment Modification*

The modification to this thought experiment involves adjusting the object's frame that is emitting the radiation. This object will be in a circular orbit some, $r$, distance away from the center of gravity of a massive object generating the gravitational field. This massive object will be stationary in the USF (consideration for a moving system will be made later). The object's frame is notated as $F'_v$. The second frame remains as it was, meaning it is moving relative the object emitting the light, but stationary in the USF, and it is essentially infinitely far away from the massive object's center of gravity. This second frame is notated as $F_\infty$. In addition, a third frame serving as the intermediary between $F'_v$ and $F_\infty$ is also considered, which is at the same gravity potential as the object, but stationary in the USF. This third frame is notated as $F'_0$. In summary, the only changes to this setup is to the object's frame, which is within a gravitational field. The three frames and their parameters are illustrated by Figure 2.

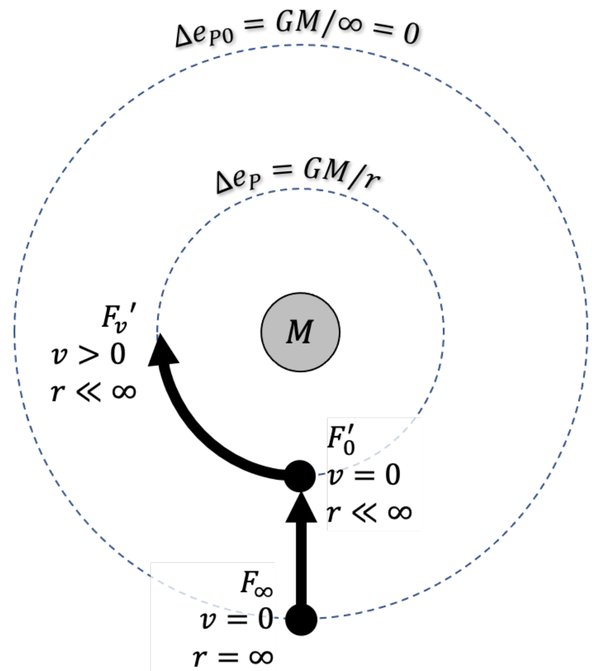


**Figure 2. Simple modified experiment.**

For notation, $E''$ is the total energy of the object considered from the frame $F'_v$; $E'$ is the total energy of the object considered from the frame $F'_0$; and $E$ is the total energy of the object considered from the frame $F_\infty$. Additionally, subscripts will be used to notate times before and after the emission of radiation. For example, $E_0$, $E'_0$ and $E''_0$ are total energies before light emission, and $E_1$, $E'_1$ and $E''_1$ are total energies after light emission.

First, consider the energy emitted as measured in frame $F'_v$, which is given in Equation (10).

$$
E''_0 - E''_1 = \frac{1}{2}L + \frac{1}{2}L = L \tag{10}
$$

Then, consider this same energy as measured in frame $F'_0$, which is given in Equation (11).

$$
\begin{aligned}
\text{Recall} : \Delta e_{K|P} &= \gamma_P^2 \Delta e_K \\
\gamma_P &= \frac{1}{\sqrt{1 - \frac{\Delta e_P}{e_T}}} \\
\gamma_{K|P} &= \frac{1}{\sqrt{1 - \frac{\Delta e_{K|P}}{e_T}}} \\
E'_0 - E'_1 &= \gamma_{K|P}(E''_0 - E''_1) = \gamma_{K|P} L
\end{aligned} \tag{11}
$$

Finally, taking into account gravitational red shift, consider this same energy as measured in frame $F_\infty$, which is given in Equation (12).

$$
E_0 - E_1 = \frac{1}{\gamma_P}(E'_0 - E'_1) = \frac{\gamma_{K|P}}{\gamma_P} L \tag{12}
$$

Then by subtraction the following is obtained:

$$
\begin{aligned}
(E_0 - E_0'') - (E_1 - E_1'') &= L\left(\frac{\gamma_{K|P}}{\gamma_P} - 1\right) \\
\Delta E_t &= L\left(\frac{\gamma_{K|P}}{\gamma_P} - 1\right)
\end{aligned}
\tag{13}
$$

It was at this point (ignoring gravity) that Einstein said, "[t]hus it is clear that the difference $[E - E'']$ can differ from the kinetic energy $[E_K]$ of the body, with respect to the other [non-object reference frame], only by an additive constant $C$..." [2]. It is proper for the same to be stated, except in this case what differs is total external energy, $E_t$, which is the combination of potential and kinetic energy.

$$
\begin{aligned}
(E_0 - E_0') &= E_{t0} + C \\
(E_1 - E_1') &= E_{t1} + C
\end{aligned}
\tag{14}
$$

Since $C$ does not change by the emission of light, the following is obtained:

$$
\Delta E_t = E_{t0} - E_{t1} = L\left(\frac{\gamma_{K|P}}{\gamma_P} - 1\right) \tag{15}
$$

The total external energy of the body with respect to $F_\infty$ diminishes as a result of the emission of light. Letting escape velocity, $v_e$, be $v_e = \sqrt{2\Delta e_P}$, and neglecting magnitudes of fourth and higher orders leads to Equation (16). Errors in this approximation, for small magnitudes of $v$ and $v_e$, are shown in Figure 3:

$$
\Delta E_t = \frac{1}{2}\frac{L}{c^2}v^2 - \frac{1}{2}\frac{L}{c^2}v_e^2 \tag{16}
$$

Therefore, it still follows that "the mass of a body is a measure of its energy-content" [2]. The total energy equation accounting for gravitational effects becomes:

$$
\begin{aligned}
E_T &= E_I + \Delta E_t \\
&= m_0c^2 + \left(\frac{\gamma_{K|P}}{\gamma_P} - 1\right)m_0c^2 = \frac{\gamma_{K|P}}{\gamma_P}m_0c^2
\end{aligned}
\tag{17}
$$

*A More General Thought Experiment Modification*

Now, it will be considered if the gravitational field were moving at velocity, $v$, in the USF. The object will still be making a circular orbit from the the gravitational field's frame. The object's frame is notated as $F_v'$. The second frame remains as it was, meaning it is moving relative the object emitting the light, but it is stationary in the USF, and it is

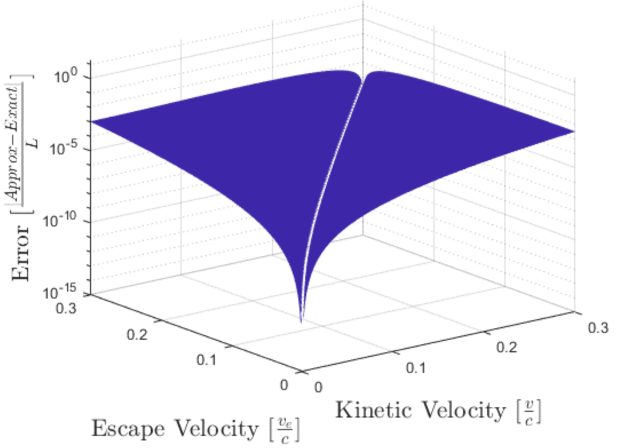


**Figure 3. Errors when ignoring higher order.**

infinitely far away from the gravitational field. This second frame is notated as $F_\infty$. In addition, two other frames serving as the intermediaries between $F_v'$ and $F_\infty$ will be considered. The third frame, serving as the first intermediary between $F_v'$ and $F_\infty$, is at the same gravity potential as the object, and moving with the gravitational field at velocity, $v$, in the USF. This third frame is notated as $F_0'$. The fourth frame, serving as the second intermediary between $F_v'$ and $F_\infty$, is infinitely far away from the massive object, but it is also moving with it at velocity, $v$, in the USF. This fourth frame is notated as $F_\infty'$. In summary, the only changes to this setup from the original is to the object's frame, which is orbiting within a gravitational field, and the gravitational field moving in the USF. The four frames and their parameters are is illustrated by Figure 4.

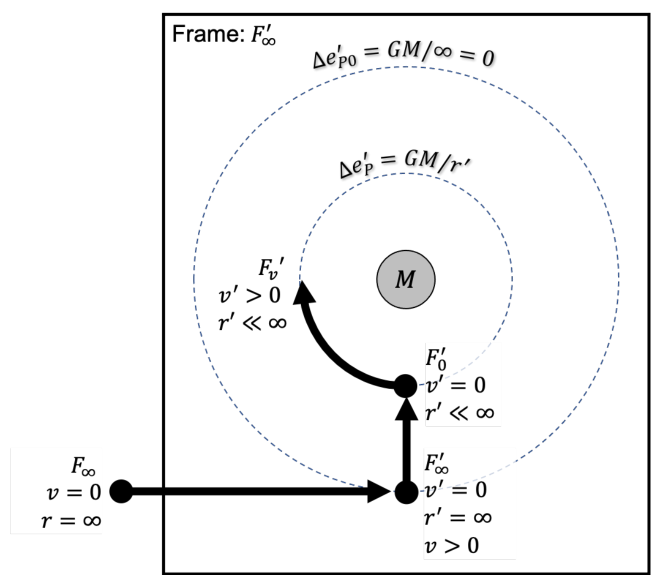


**Figure 4. General modified experiment.**

For notation, $E'''$ is the total energy of the object considered from the frame $F_v'$; $E''$ is the total energy of the object considered from the frame $F_0'$; and $E'$ is the total energy of the object considered from the frame $F_\infty'$; and $E$ is the total energy of the object considered from the frame $F_\infty$. Additionally, subscripts will be used to notate times before and after the emission of radiation. For example, $E_0$, $E_0'$, $E_0''$

and $E_0'''$ are total energies before light emission, and $E_1$, $E_1'$, $E_1''$ and $E_1'''$ are total energies after light emission.

The calculations for the total energy in $F_\infty$ in this more general modification are only slightly more complex than the simple modification. If all measurements are made in $F'_\infty$, then on the principle of relativity calculating $E'$ in $F'_\infty$ is the same as before (calculating $E$ in $F_\infty$ in the simple modification). All that remains is to transform $E'$ to $E$.

The emitted energy measured in frame $F'_\infty$ is given in Equation (18) with updated notation.

$$\begin{aligned}\text{Recall}: \Delta e_{K'|P'} &= \gamma_P'^2 \Delta e_K \\ \gamma_P' &= \frac{1}{\sqrt{1-\frac{\Delta e_P'}{e_T}}} \\ \gamma_{K|P}' &= \frac{1}{\sqrt{1-\frac{\Delta e_{K'|P'}}{e_T}}} \\ E_0' - E_1' &= \frac{\gamma_{K|P}'}{\gamma_P'} L \end{aligned} \tag{18}$$

Now, consider the emitted energy measured in frame $F_\infty$, which is given in Equation (19).

$$\begin{aligned}\gamma_K &= \frac{1}{\sqrt{1-\frac{\frac{1}{2}v^2}{e_T}}} \\ E_0 - E_1 &= \gamma_K(E_0' - E_1') = \frac{\gamma_K \gamma_{K|P}'}{\gamma_P'} L \end{aligned} \tag{19}$$

Following the same pattern as before one finds:

$$\begin{aligned} E_T &= E_I + \Delta E_t \\ &= m_0 c^2 + \left(\frac{\gamma_K \gamma_{K|P}'}{\gamma_P'} - 1\right) m_0 c^2 = \frac{\gamma_K \gamma_{K|P}'}{\gamma_P'} m_0 c^2 \end{aligned} \tag{20}$$

## 3. Complete Comparison

Again, considering energy as the product of specific energy (non-inertia part) and the rest (interpreted as the inertia generated part), specific energy and energy can be fully related as shown in Equation (21), where $I$ represents the inertia component of energy:

$$\begin{aligned} \gamma_T &= \frac{1}{\sqrt{1-\frac{\Delta e_t}{e_T}}} \\ E_T = I_T e_T &= E_I + E_t \\ &= I_I e_I + I_t \Delta e_t \\ I_T &= 2\frac{\gamma_K \gamma_{K|P}'}{\gamma_P'} m_0 \\ I_I &= 2\gamma_T^2 m_0 \\ I_t &= 2\left(\frac{\gamma_K \gamma_{K|P}'}{\gamma_P'} - 1\right) \frac{c^2}{v^2 + v_e^2} m_0 \\ &= 2\frac{\frac{\gamma_K \gamma_{K|P}'}{\gamma_P'} - 1}{1-\gamma_T^{-2}} m_0 \end{aligned} \tag{21}$$

## 4. Conclusion

In conclusion, specific energy relates to energy as one of two factors. Additionally, for a complete comparison between specific energy and energy, a more general thought experiment was conducted factoring in gravitational effects to determine potential energy's relation to total energy.

This investigative series into the theory of universal specificity has developed enough tools and concepts that one of the original questions can now be addressed: is there a way to objectively determine which inertial reference frame is the USF? That is the focus of the next investigation.

## References


[1] R. Feynman, *The Feynman Lectures on Physics*, 2012. [Online]. Available: https://www.feynmanlectures.caltech.edu [Accessed: 20-Aug-2022].

[2] A. Einstein, *Does the inertia of a body depend upon its energy-content?*. [Online]. Available: https://www.fourmilab.ch/etexts/einstein/E_mc2/e_mc2.pdf. [Accessed: 21-Aug-2022].