# Light's equivalence principle (LEP) in the invariant system

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## INTRODUCTION

In contrast, the mass in the energy-mass equivalence equation [1] has two interpretations [2]. Interpretation 1 is that energy and mass are not exactly the same; the energy of an objec t changes depending on velocity whereas the invariant mass does not change in any way. In terpretation 2 is that, apart from the constant $c^2$, energy and mass are exactly the same; the energy of a moving object is larger than that at rest. That is, when in motion, an object's relat ivistic mass is greater than when stationary. The majority of particle physicists have adopted Interpretation 1 [3]. We have here adopted Interpretation 2 with the equivalence principle of t he momentum of light.

### Relationships among invariant, (relativistic,) gravitational, and inertial mass:

The relativistic mass ($m_r$) of a moving object [4] can be calculated using the Lorentz factor from the invariant mass ($m_0$). However, Einstein has stated that, apart from its Lorentz factor connection, the "physical meaning of this mass is not known; it therefore is better not to use anything other than invariant mass", [5]

$$m_r = \gamma m_0 = m_0/(1 - v^2/c^2)^{1/2}. \tag{1}$$

The total energy of the object increases with the addition of kinetic energy [12],

$$E = [(m_0c^2)^2 + (pc)^2]^{1/2}. \tag{2}$$

Using $p = vE/c^2$ and $M = E/c^2$ [1], Eq. (2) is

$$E = Mc^2 = \gamma m_0c^2 = m_0c^2/(1 - v^2/c^2)^{1/2}. \tag{3}$$

Compared with the speed of light in the invariant system, the wave speed (Hamaji's light equivalence principle [6]) in another inertial system is

$$w = f\lambda = c/\gamma = (c^2 - v^2)^{1/2}. \tag{4}$$

If this increased kinetic energy ($pc$) is by interpretation 2 [3] a gravitational mass then the mass associated with the total energy is also a gravitational mass $M$. The inertial mass $m$ is the mass of the combined action of the change in gravitational mass with the energy increase (physical action), and the change in relativistic mass by scale conversion (mathematical action),

$$m = M(c/w) = \gamma M = \gamma^2 m_0. \tag{5}$$

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Hence, the inertial mass reverts to Eq. (1) if $m = \gamma M = \gamma m_0$ (see Appendix for details). This frees up the limitation that inertial mass = gravitational mass, but retains the essential equivalence principle of energy and momentum. This enables the mass and speed of another inertial system to be given without the need to perform a coordinate transformation,

$$E_0 = m_0 c^2 = m w^2 = \gamma^2 m_0 (c/\gamma)^2. \quad (6)$$

This preserves the relationship that energy is mass times the square of the speed.

My previous research involved representing energies (gravitational mass, inertial mass, and Planck's constant) of different particle speeds as an equivalence for quantum ($Mc = \Delta m \Delta w = hf/c$). In addition, $E = Mc^2$ (kinetic energy is changed to mass) does not indicate that the total energy change is always proportional to particle speed. Therefore, "energy representation of a mathematical action," and "energy change of a physical interaction" are not similar. The actual physical phenomenon should distinguish between these actions. Table A1 and A2 show their distinction.

**TABLE A1: Differences between the energies computed by the complex notation and by conventional methods**

| Total energy | Invariant energy [7] | No energy change [8] | Increase of energy | Decrease of energy |
|---|---|---|---|---|
| Gravitational mass | $Mc^2$ | $Mc^2$ | $(\uparrow M)c^2$ | $(\downarrow M)c^2$ |
| | $Mw_0^2$ | $M(\Delta v^2 + \Delta w^2)$ | $(\uparrow M)(\uparrow v^2 + \downarrow w^2)$ | $(\downarrow M)(\downarrow v^2 + \uparrow w^2)$ |
| Planck's constant | $hf_0$ | $hf$ | $h(\uparrow f)$ | $h(\downarrow f)$ |
| | $\hbar\omega_0$ | $\hbar\omega$ | $\hbar(\uparrow\omega)$ | $\hbar(\downarrow\omega)$ |
| Inertial mass [9] | $m_0 c w_0$ | $(\Delta m)c(\Delta w)$ | $(\uparrow\uparrow m)c(\downarrow w)$ | $(\downarrow\downarrow m)c(\uparrow w)$ |
| | $m_0 c \lambda_0 f_0$ | $(\Delta m)c(\Delta\lambda)f$ | $(\uparrow\uparrow m)c(\downarrow\downarrow\lambda)(\uparrow f)$ | $(\downarrow\downarrow m)c(\uparrow\uparrow\lambda)(\downarrow f)$ |

*M:* Gravitational mass, *c:* Speed of light, *v:* Particle speed, *w*: Wave speed, *h:* Planck constant, *f:* Frequency, *m:* Inertial mass, *λ:* Wavelength, *ħ:* Dirac's constant, *ω:* Angular velocity, $\Delta\Delta$: Inverse proportion, ↑: Increase, ↓: Decrease.

In the above table, the rows show the energy representation differences.
●: **Gravitational mass** is the weight as defined by universal gravitation.
●: **Planck's constant** is a physical constant of quantum theory.
●: **Inertial mass** quantifies the resistance of an object to the movement.
The columns indicate whether the energy computed in the complex notation has increased or decreased, relative to the standard computation.
●: **No energy change** denotes an inverse proportionality between the particle and wave speeds of the physical quantity (10). For example, the particle velocity of an object in free fall increases while its wave speed decreases. In addition, a photon is red (blue) shifted by a change in the gravitational field.
●: (●:) **Increase (Decrease) of energy** denotes that the particle–wave energy relationships of each physical quantity increase or decrease. For example, the kinetic energy increases (decreased) during acceleration (deceleration) of an object. This scenario equally applies to a motionless object seen by a moving observer.

**TABLE A2: This was represent the "Case of the total energy change" and "Case of the total energy no change" of the Fermion and the photon.**

| Fermion | Total energy representation | Photon | Total energy representation |
|---|---|---|---|
| Inertial motion | $E = Mc^2 = M(2\varphi + v^2 + w^2)$ | Propagation | $E = Mc^2 = M(2\varphi + w^2)$ |
| | $= hf = \hbar\omega$ | | $= hf$ |
| | $= mcw = mc\lambda f$ | | $= mcw = mc\lambda f$ |
| Acceleration by boost | $(\uparrow E) = (\uparrow M)c^2 = (\uparrow M)(2\varphi + \uparrow v^2 + \downarrow w^2)$ | Inverse Compton effect | $(\uparrow E) = (\uparrow M)c^2 = (\uparrow M)(2\varphi + w^2)$ |
| | $= h(\uparrow f) = \hbar(\uparrow \omega)$ | | $= h(\uparrow f)$ |
| | $= (\uparrow\uparrow m)c(\downarrow w) = (\uparrow\uparrow m)c(\downarrow\downarrow \lambda)(\uparrow f)$ | | $= (\uparrow m)cw = (\uparrow m)c(\downarrow \lambda)(\uparrow f)$ |
| Deceleration by friction | $(\downarrow E) = (\downarrow M)c^2 = (\downarrow M)(2\varphi + \downarrow v^2 + \uparrow w^2)$ | Compton effect | $(\downarrow E) = (\downarrow M)c^2 = (\downarrow M)(2\varphi + w^2)$ |
| | $= h(\downarrow f) = \hbar(\downarrow \omega)$ | | $= h(\downarrow f)$ |
| | $= (\downarrow\downarrow m)c(\uparrow w) = (\downarrow\downarrow m)c(\uparrow\uparrow \lambda)(\downarrow f)$ | | $= (\downarrow m)cw = (\downarrow m)c(\uparrow \lambda)(\downarrow f)$ |
| Escape from Gravitational source | $E = Mc^2 = M(\downarrow 2\varphi + \downarrow v^2 + \uparrow w^2)$ | Gravitational Red-shift | $E = Mc^2 = M(\downarrow 2\varphi + \uparrow w^2)$ |
| | $= hf = \hbar\omega$ | | $= hf$ |
| | $= (\downarrow m)c(\uparrow w) = (\downarrow m)c(\uparrow \lambda)f$ | | $= (\downarrow m)c(\uparrow w) = (\downarrow m)c(\uparrow \lambda)f$ |
| Free-fall to Gravitational source | $E = Mc^2 = M(\uparrow 2\varphi + \uparrow v^2 + \downarrow w^2)$ | Gravitational Blue-shift | $E = Mc^2 = M(\uparrow 2\varphi + \downarrow w^2)$ |
| | $= hf = \hbar\omega$ | | $= hf$ |
| | $= (\uparrow m)c(\downarrow w) = (\uparrow m)c(\downarrow \lambda)f$ | | $= (\uparrow m)c(\downarrow w) = (\uparrow m)c(\downarrow \lambda)f$ |

$\uparrow\downarrow$: Inverse proportion, $\uparrow$: Increase, $\downarrow$: Decrease.


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7. The invariant system is a system of the Lorentz factor (γ = 1) that the electromagnetic waves propagate at the same frequency and the speed of light.
8. The wavelength is inversely proportional to the inertial mass. They are also proportional to the wave velocity and inversely proportional to the energy.
9. The transversal Doppler Effect is determined by the wave speed, and is independent of energy.
10. $v^2$ includes a gravitational potential (2φ). The wave speed inversely varies with $v^2$, and the speed of light is constant. The gravitational field is integral to the fermions. Graviton exchange does not change the total energy of the quantum.