

Nothing Outran Light; the Light Had Been Slowed

— In Water the Threshold Is **0.2618** MeV and the Maximum Angle **41.3934** Degrees, While in Air the Threshold Is **78.6945** Times Higher — What Is Exceeded Is c/n and Not c — [Paper 332]

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— *From thinking to syncing.* —

Abstract

The water of a reactor glows blue. A charged particle, it is said, has travelled “faster than light”. This paper asks which speed is the one exceeded—the answer is the phase velocity c/n , and not the vacuum speed of light c . No new mathematical theorem and no new law is claimed. First, in water an electron begins to glow above a kinetic energy of **0.2618** MeV (Section 2). Second, the maximum angle is **41.3934** degrees and opens no further (Section 2). Third, this is the core of the paper. The speed of a particle at threshold is exactly the phase velocity of that medium (Section 3). Fourth, the same phenomenon demands **78.6945** times the energy in air. The closer n comes to 1, the harder the condition (Section 2). Fifth, the mass of the particle does not enter the angle. The muon threshold is **206.7683** times the electron’s, which is the mass ratio itself (Section 4). Sixth, the separator is whether c was exceeded or c/n was (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed——Cherenkov radiation, the theory of Frank and Tamm, the threshold condition, and the distinction between phase and group velocity are all standard. We do not compute the intensity of the radiation——photon yields and spectra from the Frank-Tamm formula are not entered. Only the geometric condition is looked at. We do not treat dispersion——that the refractive index varies with wavelength is a fact, but one n is fixed per medium here. It is mentioned and no more. We design no detector——the practice of ring-imaging and water Cherenkov detectors is not entered. We do not build relativity—— $\gamma = 1/\sqrt{1 - \beta^2}$ is used, but relativity itself is assumed. We make no superluminal claim——it is not written here that anything exceeds c . The opposite is shown, in numbers. Relation to earlier papers: Paper 210 showed the peak of a pulse can leave before it arrives——there a group velocity exceeded c while no information did. Here a particle exceeds c/n and never c . One phrase, “faster than light”, names at least two different things. Paper 111 asked how far light determines geometry——what determines it there is causal structure, not c/n inside a medium. Paper 300 showed whether two things share a root is decidable——by that test, exceeding c/n here and exceeding c in group velocity there have distinct roots. Paper 326 showed the square-cube law to be an identity——the threshold here likewise follows from the constraint that $\cos \theta = 1/(n\beta)$ cannot exceed 1. What is added is putting three media in one table to give the factor of 78.6945 between thresholds, stating explicitly that the threshold speed and the phase velocity are the same number, confirming with muons that the ratio of thresholds is the ratio of masses, and putting the separator on which speed of light was exceeded.

1. Notation and the Question

Setting: A charged particle of speed $v = \beta c$ moves through a medium of refractive index n . When $\beta n > 1$ it emits light at an angle θ to its direction of travel, given by

$$\cos \theta = \frac{1}{n\beta}.$$

Observation 1.1

The formula means nothing unless $\cos \theta \leq 1$. That is, $n\beta \geq 1$, hence $\beta \geq 1/n$ ——the threshold is fixed in advance, by the geometry.

Observation 1.2

The usual gloss is that “the particle is faster than light”. But relativity demands $\beta < 1$ —— $\beta \geq 1/n$ and $\beta < 1$ do not conflict, because $1/n < 1$ whenever $n > 1$.

Observation 1.3

The way of measuring is fixed first.The electron rest mass is 0.51099895 MeV and the kinetic energy is $E_k = mc^2(\gamma - 1)$ ——written as kinetic energy, not total energy.

Question: Which speed is the one exceeded?

2. Across Three Media the Threshold Opens by a Factor of 78.6945

Calculation 2.1: Thresholds and maximum angles for three media (computed in this paper).

Medium	n	Threshold $\beta = 1/n$	Electron threshold E_k	Maximum angle
Fused silica	1.458	0.685871	0.1912 MeV	46.6959°
Water	1.333	0.750188	0.2618 MeV	41.3934°
Air (one atmosphere)	1.000293	0.999707	20.6028 MeV	1.3868°

Observation 2.2

A check——the electron threshold in water agrees with the usual 0.26 MeV, and the maximum angle falls in the usual forty-one degrees.The instrument is tried on independently known values before the table is read.

Observation 2.3

The threshold in air is **78.6945** times that in water.From a change in n of 1.333 to 1.000293 alone——the closer n comes to 1, the more steeply the required energy rises.

Observation 2.4

The ordering is consistent.Larger n means a lower threshold and a wider maximum angle——silica 0.1912, water 0.2618, air 20.6028 MeV, in the reverse order of n .

Observation 2.5

The maximum angle reaches $\arccos(1/n)$ as $\beta \rightarrow 1$ and opens no further. However far the energy is raised —41.3934 degrees is the ceiling in water. Measure the angle and what you learn is the medium, not the particle’s speed.

3. The Core: The Threshold Speed Is the Phase Velocity, the Same Number

Calculation 3.1: Two speeds in water, side by side (computed in this paper).

Quantity	Value
Phase velocity of light in the medium, c/n	224900568.6 m/s
Speed of a particle at threshold, $\beta_{th}c$	224900568.6 m/s
Vacuum speed of light c	299792458.0 m/s
Shortfall against c	74891889.4 m/s (24.9812 per cent slower)

Observation 3.2

This is the core of the paper. The first two rows are the same number—not by coincidence, but because the threshold condition $\beta = 1/n$ says exactly what $v = c/n$ says.

Observation 3.3

So the “light” in “faster than light” is not the light of vacuum. What the particle exceeds is 224900568.6 m/s, not 299792458.0 m/s—it falls 24.9812 per cent short of c .

Observation 3.4

That a phase velocity is below c puts no strain on relativity. A phase velocity is the rate at which the phase of a field advances in a medium—it is not the speed at which anything is carried. Slowing what carries nothing moves no causality.

Observation 3.5

This makes a pair with Paper 210. Paper 210 wrote that in anomalous dispersion a group velocity can exceed c —there something did exceed c , and it was carrying no information. Here the particle carrying the information is itself in motion, and what it exceeds is not c .

Observation 3.6

Set side by side, the shape shows.

	What exceeds c	What carries information	Causality
Paper 210 (group velocity)	the group velocity	the front (at c)	preserved
This paper (Cherenkov)	nothing	the particle ($\beta < 1$)	preserved

Observation 3.7

Both are called “faster than light” and neither breaks causality. But for different reasons—under the criterion of Paper 300, one is “what exceeded carries no information” and the other is “nothing exceeded c at all”: distinct roots.

4. The Mass of the Particle Does Not Enter the Angle

Setting: An electron and a muon travel through the same water. Their masses differ by a factor of 206.7683.

Calculation 4.1: Compare thresholds and angles (computed in this paper).

Particle	Rest mass [MeV]	Threshold E_k [MeV]	Threshold β
Electron	0.510999	0.2618	0.750188
Muon	105.658376	54.1335	0.750188
Ratio	206.7683	206.7683	1.000000

Observation 4.2

The ratio of energies is exactly the ratio of masses. 206.7683 against 206.7683—because the threshold condition is written in β , and β contains no mass.

Observation 4.3

The rightmost column is the point. The threshold β is 0.750188 for both, exactly equal—what the medium fixes is a speed, not an energy.

Observation 4.4

So the angle cannot tell you what the particle is. Only n and β enter $\cos \theta = 1/(n\beta)$ —neither charge nor mass. An electron and a muon at the same speed emit into the same cone.

Observation 4.5

This is the shape of Paper 325. Paper 325 wrote that the size of the drop is not in the angle of the rainbow—here the mass of the particle is not in the Cherenkov angle. In both, there is no route by which the other party's information can enter the formula.

Observation 4.6

To be stated honestly—real detectors exploit this very independence. Measure the momentum separately in a magnetic field and the angle gives β , and p with β gives the mass—the mass is not in the angle, yet the angle combined with another measurement yields it. Its absence is what makes the angle useful.

5. The Separator: Was c Exceeded, or c/n ?

Observation 5.1

The separator——when “faster than light” is said, whether the comparison is against the vacuum speed of light or against the phase velocity in the medium.

	Compared against	Value in water [m/s]	Relation to relativity
Vacuum light speed	c	299792458.0	cannot be exceeded
Phase velocity	c/n	224900568.6	may be exceeded

Observation 5.2

The separator is not on the side of the particle. The same electron at the same energy glows in water and does not glow in air——what decides is the medium.

Observation 5.3

The separator can be moved. Bring n toward 1 and the threshold rises; at $n = 1$ the condition becomes $\beta \geq 1$, which no particle can meet——that there is no Cherenkov light in vacuum is not because the physics is different there. It is because the same formula becomes an unmeetable condition.

Observation 5.4

To be stated honestly——the refractive index varies with wavelength. In water n is larger for blue than for red, so blue has the lower threshold and the wider angle——one n per medium is a simplification here, and explaining the blue appearance needs dispersion. That is not entered.

Observation 5.5

Where this stands relative to Paper 111. Paper 111 asked how far light determines geometry——what determines it there is c , not c/n . Slow light inside a medium changes nothing about causal structure.

Observation 5.6

One last thing——the name of this phenomenon does not say what the comparison is against. What the “light” in “faster than light” refers to is written in the formula and not in the name——the confusion arises not because the phenomenon is difficult but because the name is one word short.

6. The Census and the Close

1. Electron threshold in water **0.2618 MeV** (Calculation 2.1): **agrees with the usual value.**
2. Maximum angle **41.3934 degrees** (Calculation 2.1): **it opens no further.**
3. Air is **78.6945 times** water (Observation 2.3): **harder as n nears 1.**
4. $c/n = 224900568.6$ m/s (Calculation 3.1): **the threshold speed, same number.**
5. **24.9812 per cent short of c** (Observation 3.3): **not exceeded.**
6. A different exceeding from Paper 210 (Observation 3.6): **there, what exceeded carried nothing.**
7. Muon threshold **206.7683 times** (Calculation 4.1): **the mass ratio itself.**
8. Threshold β is **0.750188** for both (Observation 4.3): **the medium fixes a speed.**
9. Neither mass nor charge in the angle (Observation 4.4): **the shape of Paper 325.**
10. At $n = 1$ the condition cannot be met (Observation 5.3): **vacuum is not different physics.**

Closing: The water of a reactor glows blue, it is said, because a charged particle travels “faster than light”——and that “light” is not the light of vacuum. The threshold comes from $\cos \theta = 1/(n\beta)$ being unable to exceed 1; in water the electron kinetic energy is **0.2618 MeV** and the maximum angle **41.3934 degrees**——**0.1912 MeV** in fused silica and **20.6028 MeV** in air, so air demands **78.6945 times** what water does. The closer n comes to 1, the harder the condition. And the speed of a particle at threshold is exactly the phase velocity of that medium——in water both are **224900568.6 m/s**, not by coincidence but because $\beta = 1/n$ says precisely what $v = c/n$ says. It falls **24.9812 per cent short** of the vacuum speed **299792458.0 m/s**. A phase velocity carries nothing, so exceeding it moves no causality——Paper 210 wrote that a group velocity can exceed c in anomalous dispersion, and there too what exceeded was carrying no information. Both are called “faster than light”, neither breaks causality, and the reasons are

different. Neither the mass nor the charge of the particle enters the angle—the muon’s threshold energy is **206.7683** times the electron’s, which is the mass ratio itself, while the threshold β is 0.750188 for both, exactly equal. What the medium fixes is a speed, not an energy. It is the shape Paper 325 found in the rainbow. One thing separates them—whether “faster than light” compares against c or against c/n . The separator lies not with the particle but with the medium—the same electron glows in water and not in air. Bring n to 1 and the condition becomes $\beta \geq 1$, which no particle can meet: there is no Cherenkov light in vacuum not because the physics differs there, but because the same formula becomes unmeetable. One last thing—the name of this phenomenon does not say what the comparison is against. What the “light” refers to is written in the formula and not in the name. The confusion arises not because the phenomenon is difficult but because the name is one word short.

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