A HUGE INCONSISTENCY IN CHERENKOV'S HISTORIC EXPERIMENTAL SETUP IN 1934.

ALEXIS ZAGANIDIS

ABSTRACT. A huge inconsistency in Cherenkov's historic experimental setup in 1934 has been found. In a first calculatory part (involving a lot of Compton scattering formulas), we derive the theoretical minimal apparent magnitude ($m_{astro} = +12.39$) of the Cherenkov radiation from the historic experimental setup (drawing by Cherenkov in 1934). Equivalently, the Cherenkov radiation from the historic experimental setup (drawing by Cherenkov in 1934) is visible, by a perfect naked eye ($m_{Naked-Eye} = +7.5$), with a minimal amount of 9 361.81 mg Radium-226 instead of an official amount of 103.6 mg Radon-226. In a second part, we summarize the technological & scientific & societal consequences of that huge inconsistency.
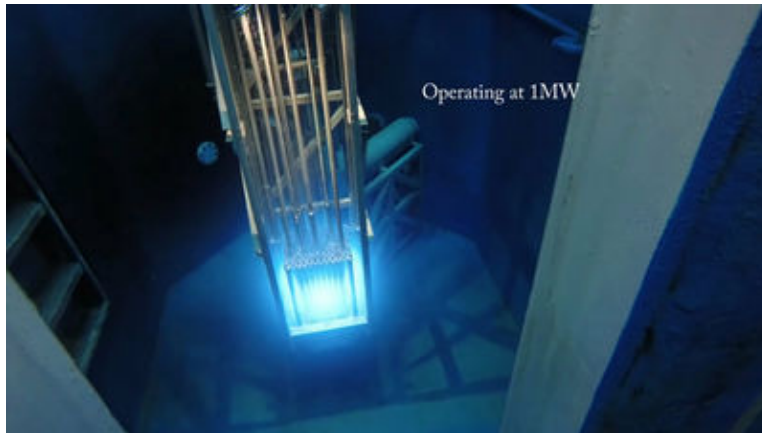
FIGURE 1. Cherenkov radiation of the Breazeale Nuclear Reactor running at $1MW$.

The first step is to derive, the relative velocity v_i/c of the Compton electron, from the scattered γ-rays emitted by the radioactive source of 103.6 mg Radium-226, with the scattering angle θ from the collision between an electron and an incoming γ photon of energy $E_{\gamma,i}$:
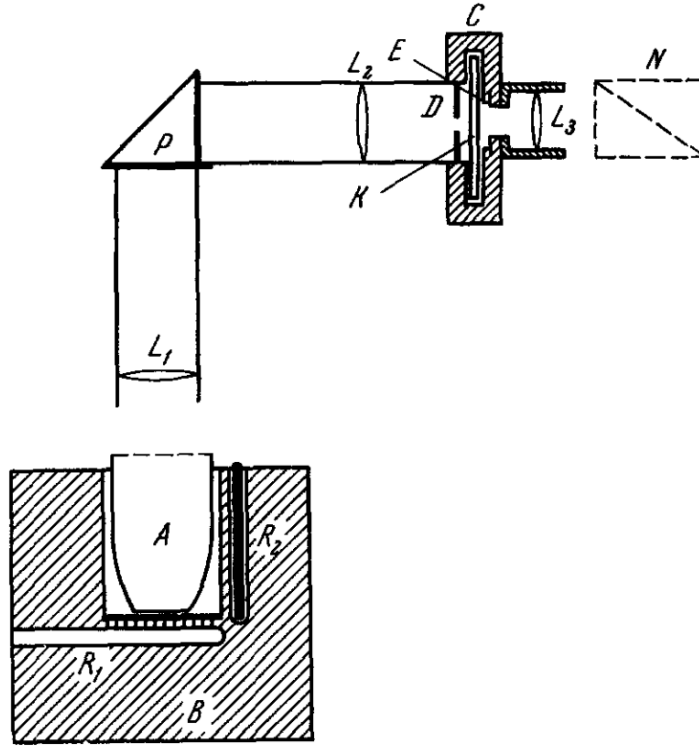
FIGURE 2. Scheme of the experimental setup (drawing by Cherenkov in 1934).

$$(1) \qquad E_e + \tilde{E}_{\gamma,i} = E_{\gamma,i} + m_e c^2 \ \& \ \vec{p}_e + \vec{p}_{\gamma,i} = \frac{E_{\gamma,i}}{c}\vec{e}_x$$

$$(2) \qquad E_e = E_{\gamma,i} + m_e c^2 - \tilde{E}_{\gamma,i} \ \& \ \vec{p}_e c = E_{\gamma,i}\vec{e}_x - \vec{p}_{\gamma,i}c$$

$$(3) \qquad E_e^2 - m_e^2\,c^4 = E_{\gamma,i}^2 + \tilde{E}_{\gamma,i}^2 - 2\,E_{\gamma,i}\tilde{E}_{\gamma,i} + 2\,m_e c^2\left(E_{\gamma,i} - \tilde{E}_{\gamma,i}\right)$$

$$(4) \qquad E_e^2 - m_e^2\,c^4 = E_{\gamma,i}^2 + \tilde{E}_{\gamma,i}^2 - 2\,E_{\gamma,i}\tilde{E}_{\gamma,i}\,Cos\,(\theta)$$

$$(5) \qquad 1 - Cos\,(\theta) = m_e c^2\left(1/\tilde{E}_{\gamma,i} - 1/E_{\gamma,i}\right)$$

$$(6) \qquad E_e/\left(m_e c^2\right) = 1 + E_{\gamma,i}/\left(m_e c^2\right) - \left(m_e c^2/E_{\gamma,i} + 1 - Cos\,(\theta)\right)^{-1}$$

$$(7) \quad v_i\left(E_{\gamma,i},\theta\right)/c = \sqrt{1 - m_e^2 c^4/E_e^2}$$

$$(8) \qquad = \sqrt{1 - \left(1 + E_{\gamma,i}/\left(m_e c^2\right) - \left(m_e c^2/E_{\gamma,i} + 1 - Cos\,(\theta)\right)^{-1}\right)^{-2}}$$

$$(9) \qquad m_e\,c^2 = 510\,999\ eV$$

$$(10)$$

where the energy $E_{\gamma,i}$ of the γ photons are given by the Figure 3 and listed below :

(11) $E_{\gamma,i} = (46.5, 242, 295, 352, 609, 768, 934, 1120, 1238, 1378, 1764, 2204)\, keV$

Isotope	Decay type	half-life	Gamma energy [keV]	Relative probability
^{222}Rn	α	3.8 d		
^{218}Po	α	3.1 m		
^{214}Pb	β	26.8 m	242	7%
			295	18%
			352	36%
^{214}Bi	β	19.9 m	609	45%
			768	5%
			934	3%
			1120	15%
			1238	6%
			1378	4%
			1764	15%
			2204	5%
^{214}Po	α	164 μs		
^{210}Pb	β	22.3 y	46.5	4%
^{210}Po	α	138 d		
^{206}Pb				

FIGURE 3. The Radon-222 decay chain. Gamma rays with relative probability smaller than 3% are omitted.

The second step is to derive the scattered fraction $f_{\gamma,i,A}$ of the γ-rays, emitted by the radioactive source of 103.6 mg Radium-226, inside the vessel A :

(12)

$$f_{\gamma,i,A} = \int_{-h_A/2}^{h_A/2} \frac{dz_2}{h_A} \int_{-h_A/2}^{h_A/2} dz_1 \int_0^{D_A/2} dr \int_0^{2\pi} r\ d\theta\ \frac{\mu_{\gamma,i}}{4\pi}\ \frac{e^{-\mu_{\gamma,i}\sqrt{(r\ Cos(\theta)+b_2)^2+r^2\ Sin^2(\theta)+(z_1-z_2)^2}}}{\left(r\ Cos\left(\theta\right)+b_2\right)^2 + r^2\ Sin^2\left(\theta\right) + \left(z_1-z_2\right)^2}$$

(13)

$$= (4.3427, 3.4863, 3.3320, 3.1882, 2.7172, 2.5120, 2.3384, 2.1781, 2.0903, 1.997, 1.7869, 1.6040)\ \%$$

(14)

$$\mu_{\gamma,i} = \frac{1+1+8}{1+1+16} \times 1000 \times \mathcal{N}_A \times \rho_{water} \times r_0^2 \times \tilde{\sigma}\left(E_{\gamma,i}/\left(m\ c^2\right)\right)$$

(15)

$$= (21.34, 14.38, 13.41, 12.55, 10.02, 9.03, 8.23, 7.53, 7.15, 6.77, 5.92, 5.22)\ m^{-1}$$

(16)

$$h_A = 0.050\ m\ \&\ b_2 = 0.025\ m\ \&\ D_A = 0.030\ m$$

(17)

$$\mathcal{N}_A = 6.02214076 \times 10^{23}\ \&\ r_0 = \alpha \frac{\hbar\ c}{m_e c^2} = 2.82017 \times 10^{-15}\ m$$

where the Compton cross section $\sigma\left(E_{\gamma,i}\right)$ is given in the appendix.

The third step is to derive the visible Cherenkov radiation energy $E_{Cherenkov,A,V,i}$ of the Compton electron, from the scattered γ-rays emitted by the radioactive source of 103.6 mg Radium-226, from the mean path length $l_{A,i}$ of the vessel A and from the following Frank–Tamm formula :

(18)

$$E_{Cherenkov,A,V,i} = l_{A,i} \int_0^\pi \frac{Sin\left(\theta\right)d\theta}{\tilde{\sigma}\left(E_{\gamma,i}/\left(m\ c^2\right)\right)} \frac{d\tilde{\sigma}}{d\theta}\left(E_{\gamma,i}/\left(m\ c^2\right),\theta\right) \int_{\lambda_{min}}^{\lambda_{max}} d\lambda$$

(19)

$$\frac{e^2}{4\pi\ \epsilon_0} \frac{(2\pi)^2}{\lambda^3}\left(1 - \frac{c^2}{v^2\left(E_{\gamma,i},\theta\right)n^2\left(\lambda\right)}\right) H\left(1 - \frac{c^2}{v^2\left(E_{\gamma,i},\theta\right)n^2\left(\lambda\right)}\right)$$

(20) $\qquad D_A = 0.030\ m\ \&\ \lambda_{min} = 380\ nm\ \&\ \lambda_{max} = 700\ nm$

(21) $\qquad e = 1.602\ 10^{-19}\ C\ \&\ \epsilon_0 = 8.854 \times 10^{-12}\ s^2\ C^2/\left(kg\ m^3\right)$

(22) $\qquad l_{A,i} = Min\left(l_A = 0.016326\ m, 0.004\ m \times (E_{\gamma,i}/MeV)^{-5/3.65}\right)$

where the relative velocity $v\left(E_{\gamma,i}\right)/c$, from the Compton electron, is given by the Equations 7 & 8, where the energy $E_{\gamma,i}$, from the γ photons, is given by the Figure 3 and where the refractive index $n^2(\lambda)$, from the water, is given by the Figure 4 & 5. The Compton cross section $\sigma\left(E_{\gamma,i}\right)$ and its differential $\frac{d\tilde{\sigma}}{d\theta}\left(E_{\gamma,i}/\left(m\ c^2\right),\theta\right)$ are given in the appendix. The mean path $l_{A,i}$ of the Compton electron, from the scattered γ-rays emitted by the radioactive source of 103.6 mg Radium-226, can not be longer than the maximal range of β particles in water, given in the logarithmic plot of the Figure 6, with a polynomial attenuation. Further more, the mean path $l_{A,i}$ can not be longer than the mean path $l_A = 0.016326\ m$ of an isotropic

homogeneous emission, inside the vessel $\mathcal{A}$, without any back reflections on its walls.

Since the diameter $D_{\mathcal{A}}$ of the vessel $\mathcal{A}$ is very small, the Cherenkov radiation energy $E_{Cherenkov,\mathcal{A},i}$ of the Compton electron, from the scattered γ-rays emitted by the radioactive source of $103.6\ mg$ Radium-226, is $\times 0.100454\%$ smaller than the energy of the scattered γ photons.

Since the diameter $D_{\mathcal{A}}$ of the vessel $\mathcal{A}$ is very small and the Cherenkov radiation is mostly ultraviolet, the visible Cherenkov radiation energy $E_{Cherenkov,\mathcal{A},V,i}$ of the Compton electron, from the scattered γ-rays emitted by the radioactive source of $103.6\ mg$ Radium-226, is $\times 0.00613558\%$ smaller than the energy of the scattered γ photons.
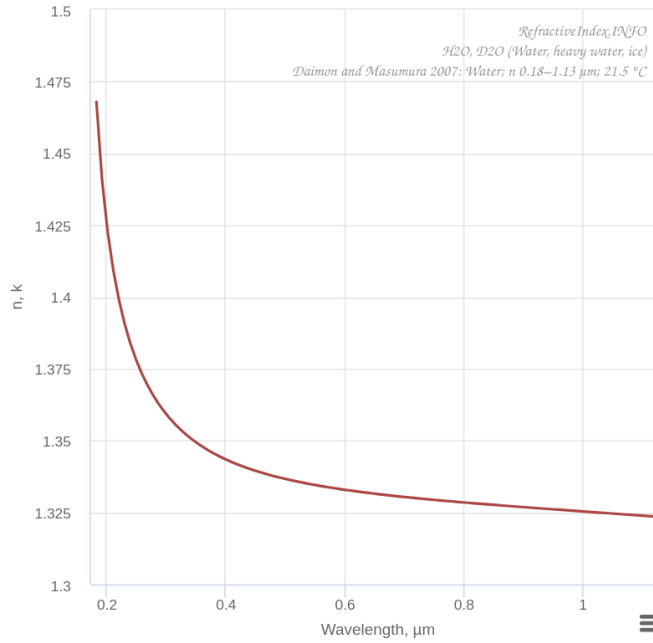

FIGURE 4. Plot dispersion of the water's refractive index.

$$n^2 - 1 = \frac{5.689093832{\times}10^{-1}\lambda^2}{\lambda^2 - 5.110301794{\times}10^{-3}} + \frac{1.719708856{\times}10^{-1}\lambda^2}{\lambda^2 - 1.825180155{\times}10^{-2}} + \frac{2.062501582{\times}10^{-2}\lambda^2}{\lambda^2 - 2.624158904{\times}10^{-2}} + \frac{1.123965424{\times}10^{-1}\lambda^2}{\lambda^2 - 1.067505178{\times}10}$$

FIGURE 5. Formula dispersion of the water's refractive index.

The fourth step is to derive the power flow $F_{Cherenkov,V,\mathcal{A}}$ of the visible Cherenkov radiation at the aperture of the vessel $\mathcal{A}$:
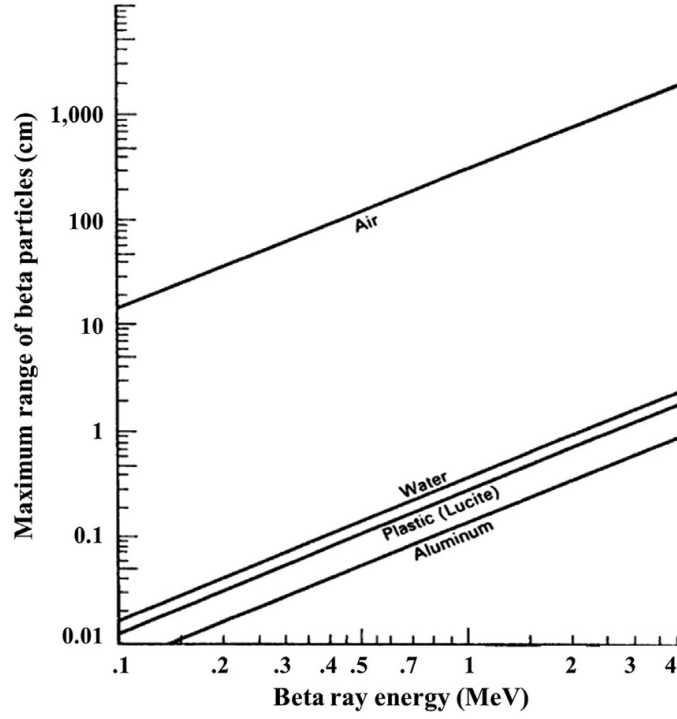
FIGURE 6. The maximal Range of β particles in water and in various other substances.

(23)
$$F_{Cherenkov,\mathcal{A},V} = m_{Radium-226} \times a_{Radium-226} \times \frac{R_{\mathcal{A}}\left(R_{Ti}=0.55\right)}{(\pi/4)\,D_{\mathcal{A}}^2} \times \sum_i p_{\gamma,i} \times f_{\gamma,i,A} \times E_{Cherenkov,V,i}$$

(24)
$$= 0.1036 \times 0.988 \times 3.7 \times 10^{10} \times \frac{4 \times 0.513198}{\pi \times 0.030^2} \times \sum_i p_{\gamma,i} \times f_{\gamma,i,A} \times E_{Cherenkov,V,i}$$

(25)
$$= 0.70566 \; \mu W/m^2$$

(26)
$$R_{\mathcal{A}}\left(R_{Ti}=0.55\right) = 0.513198$$

(27)
$$p_{\gamma,i} = (4, 7, 18, 36, 45, 5, 3, 15, 6, 4, 15, 5)\,\%$$

where the emission probability $p_{\gamma,i}$ of the γ photons and the energy $E_{\gamma,i}$ of the γ photons are given by the Figure 3. The factor $R_{\mathcal{A}}\left(R_{Ti}=0.55\right)$ is the probability, of a Cherenkov photon, to go out of the vessel $\mathcal{A}$ without being absorbed by its Titanium walls (having a Reflectance R_{Ti} of the vessel $\mathcal{A}$ walls equal to 0.55).

The filth step is to derive the maximal power flow of the visible Cherenkov radiation $F_{Cherenkov,Retina,V}^{max}$, on the observer's retina, from the second law of thermodynamic about the entropy, from the optical efficiency of the experimental setup and from the optical efficiency of the the observer's naked eye:

(28) $\quad F_{Cherenkov,Retina,V}^{max} = \eta_{Optical} \times F_{Cherenkov,\mathcal{A},V}$

(29) $\qquad\qquad = \eta_{Lense}^{3} \times \eta_{Prism} \times \eta_{Naked\ Eye} \times F_{Cherenkov,\mathcal{A},V}$

(30) $\qquad\qquad = 0.9^{3} \times 0.85 \times 0.835 \times F_{Cherenkov,\mathcal{A},V} \times$

(31) $\qquad\qquad = 0.398697\ \mu W/m^{2}$

(32) $\qquad\quad \eta_{Lense} = 0.90\ \&\ \eta_{Prism} = 0.85\ \&\ \eta_{Naked\ Eye} = 0.835$

The sixth step is to derive the power flow of the visible astrophysical radiation $F_{Astro,Retina,V}^{max}$, on the observer's retina, from an astrophysics object with an apparent magnitude equal to $m_{astro} = +12.39$ and to compare that power flow $F_{Astro,Retina,V}^{max}$ with the maximal power flow of the visible Cherenkov radiation $F_{Cherenkov,Retina,V}^{max}$:

(33)
$$F_{Astro,Retina,V}\left(m_{astro} = +12.39\right) = 10^{-\frac{m_{astro}-m_{sun}}{2.5}} \times F_{Sun} \times \frac{\frac{\pi}{4}D_{Pupil}^{2}}{\frac{\pi}{4}\theta_{min}^{2}D_{Naked-Eye}^{2}}$$

(34) $\qquad\qquad\qquad = 10^{-\frac{12.39+26.74}{2.5}} \times 1370 \times \dfrac{\frac{\pi}{4} \times 0.008^{2}}{\frac{\pi}{4} \times (\pi/180/60)^{2} \times 0.024^{2}}$

(35) $\qquad\qquad\qquad = 0.400891\ \mu W/m^{2}$

(36)
$$\frac{F_{Astro,Retina,V}\left(m_{astro} = +12.39\right)}{F_{Cherenkov,Retina,V}^{max}} = 1.0055$$

(37) $\qquad\qquad\qquad m_{astro} = +12.39\ \&\ m_{sun} = -26.74\ \&\ F_{Sun} = 1\ 370\ W$

(38) $\qquad\qquad\quad D_{Pupil} = 0.008\ m\ \&\ D_{Naked-Eye} = 0.024\ m\ \&\ \theta_{min} = \pi/10\ 800\ rad$

(39)

Finally, we can derive the theoretical minimum amount $m_{Radium-226}^{min,th}$ of Radium-226 in order to observe the visible Cherenkov radiation, on the observer's retina, with a perfect optical experimental setup :

$$(40) \qquad \frac{m_{Radium-226}^{min,th}}{m_{Radium-226}} = 10^{-\frac{m_{astro}-m_{Retina}^{min}}{2.5}}$$

$$(41) \qquad = 10^{\frac{12.39-7.5}{2.5}}$$

$$(42) \qquad = 90.3649$$

$$(43) \qquad m_{Radium-226}^{min,th} = \frac{m_{Radium-226}^{min,th}}{m_{Radium-226}} \times m_{Radium-226}$$

$$(44) \qquad = 9\,361.81\ mg$$

$$(45) \qquad \frac{m_{Radium-226}^{range}}{m_{Radium-226}} = \frac{m_{Radium-226}^{min,th}}{m_{Radium-226}} \times (3,10)$$

$$(46) \qquad = (271.095, 903.649)$$

$$(47) \qquad m_{Radium-226}^{range} = m_{Radium-226}^{min} \times (3,10)$$

$$(48) \qquad = (28\,085.4\ mg, 93\,618.1\ mg)$$

To conclude, we have derived the theoretical minimal mass $m_{Radium-226}^{min,th}$ of $9\,361.81\ mg$ Radium-226 in order to observe the visible Cherenkov radiation, on the observer's retina, by assuming a 100% sealed lead ampule with no radon gas leaks, a 100% γ-transparent lead ampule, a 100% γ-transparent wooden support B, a perfect optical experimental setup and a perfect observer's naked eye ($m_{Naked-Eye} = +7.5$). A realistic mass range $m_{Radium-226}^{range}$ of Radium-226 in order to observe the visible Cherenkov radiation, on the observer's retina, is $(28\,085.4\ mg, 93\,618.1\ mg)$. In 1934, that realistic mass range $m_{Radium-226}^{range}$ of Radium-226 was absolutely enormous & monstrous.

For comparison, the following historical reference about the Radium-226 : In 1921, U.S. President Warren G. Harding received her at the White House to present Marie Curie with the 1000 milligrams of radium collected in the United States, and the First Lady praised her as an example of a professional achiever who was also a supportive wife.

It obviously means that Cherenkov have lied about the Cherenkov's historic experimental setup in 1934. The most reasonable explanation, Cherenkov has thought & written about a completely fictive & theoretical setup, which minimizes the amount of radioactive materials involved, in order to keep secret the much larger amounts of radioactive materials involved in the real Cherenkov's historic experimental setup. The much larger amounts of radioactive materials would be obtained with an home-made Russian nuclear reactor in 1934. A Russian homemade nuclear reactor is a rotating mixing tank (having a very good sealing and robustness) containing a few tons of graphite (without boron impurities) and with a tiny continuous incoming flow of natural uranium powder (incoming flow regulated according to the tank temperature).

This is the subtlety of Cherenkov's scientific fraud : as prodigious and talented as the secret sciences are, they must be neither rewarded nor valued.

Appendix :

(49) $\quad \dfrac{d\tilde{\sigma}}{d\theta}\left(\epsilon = E_{\gamma,i}/\left(m\ c^2\right),\theta\right) = \dfrac{1}{r_0^2}\displaystyle\int_0^{2\pi} d\phi \dfrac{d\sigma}{d\Omega}\left(\epsilon = E_{\gamma,i}/\left(m\ c^2\right),\theta\right)$

(50) $\quad = \dfrac{\pi\left(1 + Cos^2\left(\theta\right)\right)}{\left(1 + 2\ \epsilon\ Sin^2\left(\theta/2\right)\right)^2}\left(1 + \dfrac{4\epsilon^2 Sin^4\left(\theta/2\right)}{\left(1 + Cos^2\left(\theta\right)\right)\left(1 + 2\ \epsilon\ Sin^2\left(\theta/2\right)\right)}\right)$

(51)

(52) $\quad \tilde{\sigma}\left(\epsilon = E_{\gamma,i}/\left(m\ c^2\right)\right) = \dfrac{1}{r_0^2}\sigma\left(\epsilon = E_{\gamma,i}/\left(m\ c^2\right)\right)$

(53) $\quad = 2\pi\left(\dfrac{1+\epsilon}{\epsilon^2}\left(\dfrac{2+2\ \epsilon}{1+2\ \epsilon} - \dfrac{Log\left(1+2\ \epsilon\right)}{\epsilon}\right) + \dfrac{Log\left(1+2\ \epsilon\right)}{2\ \epsilon} - \dfrac{1+3\ \epsilon}{\left(1+2\ \epsilon\right)^2}\right)$

REFERENCES

[1] A. Zaganidis, "A huge inconsistency in Cherenkov's historic experimental setup in 1934.."
    https://drive.google.com/drive/folders/1gVY7mw3wehb9AQOo75ap3CskB2GeaBnM?usp=drive_link.
[2] Wikipedia. https://en.wikipedia.org/wiki/Cherenkov_radiation.
[3] Wikipedia. https://en.wikipedia.org/wiki/Pennsylvania_State_University_Radiation_Science_%26_Engineering_Center.
[4] Wikipedia. https://en.wikipedia.org/wiki/Pavel_Cherenkov.
[5] Wikipedia. https://en.wikipedia.org/wiki/Radioactive_decay.
[6] Wikipedia. https://en.wikipedia.org/wiki/Specific_activity.
[7] Wikipedia. https://en.wikipedia.org/wiki/Decay_chain.
[8] Wikipedia. https://en.wikipedia.org/wiki/Marie_Curie.
[9] Wikipedia. https://en.wikipedia.org/wiki/Radium.
[10] Wikipedia. https://en.wikipedia.org/wiki/Radon-222.
[11] Wikipedia. https://en.wikipedia.org/wiki/Gamma_ray.
[12] Wikipedia. https://en.wikipedia.org/wiki/Attenuation_coefficient.
[13] Wikipedia. https://en.wikipedia.org/wiki/Avogadro_constant.
[14] Wikipedia. https://en.wikipedia.org/wiki/Cross_section_(physics).
[15] Wikipedia. https://en.wikipedia.org/wiki/Elastic_collision.
[16] Wikipedia. https://en.wikipedia.org/wiki/Solid_angle.
[17] Wikipedia. https://en.wikipedia.org/wiki/Special_relativity.
[18] Wikipedia. https://en.wikipedia.org/wiki/Compton_scattering.
[19] Wikipedia. https://en.wikipedia.org/wiki/Klein%E2%80%93Nishina_formula.
[20] PhysicsRutgers. https://www.physics.rutgers.edu/~eandrei/389/compton%20cross%20section.pdf.
[21] Wikipedia. https://en.wikipedia.org/wiki/Beta_decay.
[22] Wikipedia. https://en.wikipedia.org/wiki/Attenuation_coefficient.
[23] Wikipedia. https://en.wikipedia.org/wiki/Cherenkov_radiation.
[24] Wikipedia. https://en.wikipedia.org/wiki/Frank%E2%80%93Tamm_formula.
[25] Wikipedia. https://en.wikipedia.org/wiki/Refractive_index.
[26] Wikipedia. https://en.wikipedia.org/wiki/Optical_properties_of_water_and_ice.
[27] RefractiveIndex. https://refractiveindex.info/?shelf=main&book=H2O&page=Daimon-21.5C.
[28] Wikipedia. https://en.wikipedia.org/wiki/Sellmeier_equation.
[29] Wikipedia. https://en.wikipedia.org/wiki/Reflectance.
[30] Wikipedia. https://en.wikipedia.org/wiki/Titanium.
[31] Wikipedia. https://en.wikipedia.org/wiki/Second_law_of_thermodynamics.
[32] Wikipedia. https://en.wikipedia.org/wiki/Luminous_flux.
[33] Wikipedia. https://en.wikipedia.org/wiki/Retina.
[34] Wikipedia. https://en.wikipedia.org/wiki/Transmittance.

[35] Wikipedia. https://en.wikipedia.org/wiki/Lens.

[36] Wikipedia. https://en.wikipedia.org/wiki/Prism.

[37] Wikipedia. https://en.wikipedia.org/wiki/Naked_eye.

[38] Wikipedia. https://en.wikipedia.org/wiki/Retina.

[39] Wikipedia. https://en.wikipedia.org/wiki/Retina.

[40] Wikipedia. https://en.wikipedia.org/wiki/Retina.

[41] Wikipedia. https://en.wikipedia.org/wiki/Astrophysics.

[42] Wikipedia. https://en.wikipedia.org/wiki/Apparent_magnitude.

[43] Wikipedia. https://en.wikipedia.org/wiki/Sun.

[44] CloudyNights. https://www.cloudynights.com/topic/701405-can-you-really-see-7-magnitude-stars-with-your-eyes-in-bortle-1-or-2-skies/.

[45] П. А. Черенков, "Видимое свечение чистых жидкостей под действием -радиации," *Усп. физ. наук*, vol. 93, no. 10, pp. 385–388, 1967.

[46] P. A. Čerenkov, "Visible radiation produced by electrons moving in a medium with velocities exceeding that of light," *Phys. Rev.*, vol. 52, pp. 378–379, Aug 1937.

[47] E. P. Cherenkova, "The discovery of the cherenkov radiation," *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 595, no. 1, pp. 8–11, 2008. RICH 2007.

[48] E. Bellotti, C. Broggini, G. Carlo, M. Laubenstein, and R. Menegazzo, "Precise measurement of the 222rn half-life: A probe to monitor the stability of radioactivity," *Physics Letters B*, vol. 743, 01 2015.

[49] U. Lee, W. N. Choi, J. Bae, and H. Kim, "Fundamental approach to development of plastic scintillator system for in situ groundwater beta monitoring," *Nuclear Engineering and Technology*, vol. 51, 05 2019.