

INNOVATION IN MAGNETICS

Helmholtz Coil Systems



- 350mm to 2m diameter coils
- Orthogonality correction using PA1
- Active compensation using CU2 (except 2m coil)
- Control software available

Mag-13 Three-axis Magnetic Field Sensors



- Noise levels down to $<6\text{pT}_{\text{rms}}/\sqrt{\text{Hz}}$ at 1Hz
- Measuring ranges from ± 70 to $\pm 1000\mu\text{T}$
- Bandwidth to 3kHz

US distributor

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human terms. I was particularly drawn in by Zangwill's mention of Anderson's Anglophilia and his association with leading researchers at the University of Cambridge. In that context, two of Anderson's "four facts"—that computers will not replace scientists and that good science has aesthetic qualities—resonate with Brian Josephson's interests in the past 20-odd years.

I met Josephson at an international conference, titled Home and the World: Rabindranath Tagore at the End of the Millennium, which was held by the University of Connecticut in September 1998. Josephson spoke about the poet-philosopher Tagore (1861–1941) and science.¹ From my relatively brief encounter with him, I understood at the time that Josephson was especially interested in the area of mind–matter interactions, and that, of course, had some relevance to the well-known 1930 conversation that Tagore had with Albert Einstein on reality and the human mind.² Mind–matter interactions have also been an area of sustained interest for many leading scientists, including Ilya Prigogine and Roger Penrose.

It is also quite noteworthy that Zangwill mentions Charles Kittel as one of Anderson's mentors at Bell Labs. Many of us pursuing physics and engineering in India in the 1970s were introduced to Kittel's classic textbook *Introduction to Solid State Physics*, which was foundational to our understanding of the subject.

References

1. B. Josephson, in *Rabindranath Tagore: Universality and Tradition*, P. C. Hogan, L. Pandit, eds., Fairleigh Dickinson U. Press (2003), p. 107.
2. M. Popova, "When Einstein met Tagore: A remarkable meeting of minds on the edge of science and spirituality," *Marginalian* (27 April 2012).

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CO₂ air-capture costs

David Kramer's "A windfall for US carbon capture and storage" (January 2022, page 22) mentions the \$3.5 billion appropriated by the US government for direct air capture. I would like to point out that the energy costs of capturing

carbon dioxide already diluted in the atmosphere would be prohibitive.

Methods tried so far employ a reusable absorber cycled between absorption and emission, with an input of energy required at one or both parts of the cycle. The unavoidable energy requirement for a cycle can be calculated from the entropy change ΔS of the CO₂ going from its present atmospheric concentration of about 400 ppm to a concentration needed for disposal or use, say 1 atmosphere.

Per unit mass and at room temperature T , that energy would be $T\Delta S = RT/M \ln(10^6/400) = 4.4 \times 10^5 \text{ kJ/ton (t)}$, where R is the molar gas constant and M the molar mass. If you assume the energy is applied electrically, and at a present US price of 12¢/kWh, the energy cost is \$15/t. So far there are no reports of technologies that are anywhere close to that energy requirement or cost.

Earth's atmosphere weighs $5.2 \times 10^{15} \text{ t}$. The unavoidable entropy cost to remove just 1 ppm (by volume) of CO₂, or $7.9 \times 10^9 \text{ t}$, would be \$120 billion. After recovery at 1 atmosphere, there are the added costs of disposal, which is complicated by the residual atmospheric gases in the recovered CO₂.

The cost could be reduced if the energy is somehow supplied directly rather than after conversion to electricity. But no energy source is free because its energy could otherwise be converted to electricity and sold.

The costs of mineralization are more difficult to estimate. The absorber is used only once, not cycled. Costs might include those for accessing, processing by crushing and dispersing, and gathering and disposing of the absorber.

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