There Are Three Ways of Doing No Work, and the Zero Sits in a Different Place in Each

— reactive power is zero only on average, a magnetic field has an inner product of exactly $\mathbf{0}$, and the displacement current has no zero at all — [Paper 522]

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— *From thinking to syncing.* —

Abstract

The same phrase, “does no work”, is used in three electrical settings.What this paper shows is that the zero sits in a different place in each, in a different term of Poynting’s ledger.No new theorem or law is claimed. First, for reactive power only the time average is zero——the mean is $\mathbf{1.004 \times 10^{-17}}$, while the instantaneous power is $\mathbf{0.500000}$ and the r.m.s. current is $\mathbf{0.707107}$ (Section 2). **Second, inserting a series resistor makes the mean $\mathbf{0.250000}$——the other side of the boundary: the zero belonged to the circuit, not to alternating current** (Section 2). **Third, for a magnetic field the inner product itself is zero——the normalised inner product of force and velocity is $\mathbf{0.000 \times 10^{0}}$, zero before any average is taken** (Section 3). **Fourth, and yet the velocity does move——the speed goes only from $\mathbf{0.911043357914}$ to $\mathbf{0.911043357916}$, while the $\boldsymbol{x}$ component goes from $\mathbf{0.700000}$ to $\mathbf{0.559541}$** (Section 3). **Fifth, and this is the core.For the displacement current there is no zero at all——the quantity simply does not live in the $\mathbf{J \cdot E}$ term, while the stored energy grows at $\mathbf{8.854187813 \times 10^{-8}}$ watts and matches the inflow through the side wall with ratio $\mathbf{1.000000000000}$** (Section 4). **Sixth, the separator is which zero it is——a zero average, a zero inner product, or absence from the term: three places in one ledger** (Section 5). **Keywords**: forces that do no work, Poynting’s theorem, reactive power, Lorentz force, electromagnetic energy.

Scope of this paper (scope note): **No new theorem or law is claimed——Poynting's theorem, the definition of reactive power and the fact that the Lorentz force does no work are all standard.Energy localisation is not discussed——the freedom to add a curl to the Poynting vector is not entered; only the ledger integrated over a closed surface is used.Magnetic moments are not covered——particles with internal degrees of freedom, where a magnetic field can appear to do work, lie outside the frame.No circuit is designed——how to improve power factor is not the subject.No substance is given to the displacement current——it is said to source a magnetic field, not that charge is moving.The three are not called "the same phenomenon"——what they share is a ledger, not a mechanism.Relation to earlier papers**: **Paper 356 showed that current flows and does no work——this paper shows that its zero is a zero of the time average, by placing 0.500000 of instantaneous power beside it.Paper 410 showed that a magnetic field confines without doing work——this paper shows that its zero is a zero of the inner product, by separating speed from direction.Paper 267 showed that the displacement current is not a current——this paper shows which term of the ledger it does not live in.Paper 339 showed a comet has two tails and Paper 418 showed light has two angular momenta——both use the Poynting vector from the momentum side; this paper uses it from the energy side.Paper 300 showed that sharing a root is decidable——the three zeros are separate roots under the criterion of what a quantity must carry.Paper 481 showed a broken law can be blamed on any assumption——here the direction is reversed: with a ledger, "does no work" has exactly one destination.**What is added is **assigning the three zeros addresses in one ledger**, **measuring 0.500000 and 0.250000 as the two sides of a boundary**, **measuring that the magnetic zero holds before any averaging**, **checking that the displacement-current ledger closes to 12 digits**, and **placing the separator on which zero it is**.

1. Notation and the Question

Setting: **Poynting's theorem is the energy ledger of the electromagnetic field,**

$$\frac{\partial u}{\partial t} + \nabla \cdot \mathbf{S} = -\mathbf{J} \cdot \mathbf{E}$$

with u the stored energy, $\mathbf{S} = \mathbf{E} \times \mathbf{B}/\mu_0$ the flow, and $\mathbf{J} \cdot \mathbf{E}$ the rate of handing energy to matter.

Observation 1.1

there are only three terms.Change in storage, divergence of flow, handover to matter——to say "does no work" without saying which term vanishes is to utter a sentence with no address.

> **Observation 1.2**
>
> **a zero comes in three shapes.The time average vanishes; the quantity itself vanishes; the quantity does not appear in that term at all——the third cannot even be called a zero. It is a different term.**

Question: **which of the three is each electrical "does no work"?**

2. Reactive Power: Only the Time Average Is Zero

Computation 2.1: **drive a pure inductor ($L = 1$) with $v(t) = \cos t$, so that $i(t) = \sin t$, and average $p(t) = vi$ numerically over one period.**

quantity	value
mean power	$\mathbf{1.004 \times 10^{-17}}$
peak instantaneous power	$\mathbf{0.500000}$
r.m.s. current	$\mathbf{0.707107}$

> **Observation 2.2**
>
> **of the three numbers only one is zero.Current flows and instantaneous power sloshes——the zero appears after a full period, not at any instant.**

> **Observation 2.3**
>
> **the peak $\mathbf{0.500000}$ is the sloshing of storage.$p(t) = (1/2)\sin 2t$, at twice the frequency——energy crosses between source and inductor twice per period.**

Computation 2.4: **insert $R = 1$ in series and take the same average, obtaining $\mathbf{0.250000}$, in agreement with the closed form $V^2 R/(2|Z|^2)$.**

Observation 2.5

this is the other side of the boundary.Same alternating drive, same frequency, and the mean is no longer zero——the zero belonged to the circuit, not to the fact of alternation.

Observation 2.6

in ledger terms, $\mathbf{J} \cdot \mathbf{E}$ is not zero.At each instant energy passes between matter and field——it merely sums to zero over a period.

3. The Magnetic Field: the Inner Product Itself Is Zero

Computation 3.1: **advance a charged particle through 200000 steps in a uniform field $\mathbf{B} = (0, 0, 1)$, measuring the normalised inner product of force and velocity at every step.**

quantity	value
peak normalised inner product	$\mathbf{0.000 \times 10^{0}}$
speed (initial)	**0.911043357914**
speed (final)	**0.911043357916**
velocity x component (initial → final)	**0.700000 → 0.559541**

Observation 3.2

this zero holds before any averaging.$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$ is orthogonal to $\mathbf{v}$ by definition——a different kind of zero from reactive power: there it cancels over a cycle, here it was never there.

Observation 3.3

and still something is happening.The relative change in speed is $\mathbf{1.759 \times 10^{-12}}$, the size of the integration error, while the x component moves by $\mathbf{0.140459}$——zero work and no influence are different statements.

Observation 3.4

in ledger terms, $\mathbf{B}$ never appears in $\mathbf{J}\cdot\mathbf{E}$.The work term contains the electric field only——what Paper 410 described as confinement without work is the shape of this term.

Observation 3.5

this does not make the magnetic field irrelevant.It enters $\mathbf{S}$, and it enters u through $B^2/2\mu_0$——it is absent from one term out of three.

4. The Displacement Current: Not Even a Zero

Computation 4.1: **in the gap of a parallel-plate capacitor of area 10^{-2} square metres and separation 10^{-3} metres, raise the field at 10^{6} volts per metre per second, and at $t = 10^{-3}$ seconds compute separately the growth of stored energy and the Poynting inflow through the side wall.**

quantity	value (watts)
volume integral of $\partial u/\partial t$	$\mathbf{8.854187813 \times 10^{-8}}$
inflow through the side wall	$\mathbf{8.854187813 \times 10^{-8}}$
ratio	**1.000000000000**
$\mathbf{J}\cdot\mathbf{E}$ (no free current)	0

Observation 4.2

this is the core.With no free current in the gap, $\mathbf{J}\cdot\mathbf{E} = 0$, but nothing became zero——the quantity never lived in that term. The balance closes with two terms alone.

Observation 4.3

the ledger closes to 12 digits.The ratio of inflow to storage growth is 1.000000000000——this is a check, not a claim. Omit the displacement current as a source of $\mathbf{B}$ and no field appears, the inflow is zero, and the ledger stays open.

Observation 4.4

energy enters from the side.Not along the leads but through the cylindrical wall——as Paper 267 put it, what moves is not charge but field.

Observation 4.5

the third case is not a species of zero.A zero average means it cancels on integration; a zero inner product means it is always zero; absence from a term means the quantity is not there——only the third is not a statement about a number.

5. The Separator

Observation 5.1

the separator is which zero it is.Confusing them changes predictions——the average zero breaks when the circuit changes (0.250000), the inner-product zero breaks for no field configuration, and the absence from a term moves only if the ledger is rewritten.

Observation 5.2

by the criterion of Paper 300 concerning what a quantity carries, these are separate roots.The first needs a period, the second does not, the third is not a quantity——that the same number, zero, appears is no evidence of a shared root.

Observation 5.3

what is shared is the ledger.All three have addresses in one equation——which is not to say one phenomenon. They are different lines of one account.

Observation 5.4

the direction is opposite to Paper 481.There, a broken law could be blamed on any assumption——here, with a ledger in hand, “does no work” has exactly one destination.

Observation 5.5

what is not said.The Poynting vector admits an added curl, and localisation is not discussed——only the ledger integrated over a closed surface is used.

Observation 5.6

magnetic moments lie outside the frame.With internal degrees of freedom a magnetic field can appear to do work——the particle here is a point charge, and only then is the inner product exactly zero.

6. Roll Call and Closing

1. **reactive mean $\mathbf{1.004 \times 10^{-17}}$** (Computation 2.1): **only the average is zero.**
2. **instantaneous $\mathbf{0.500000}$, r.m.s. $\mathbf{0.707107}$** (Computation 2.1): **two non-zero quantities.**
3. **with a resistor, $\mathbf{0.250000}$** (Computation 2.4): **the other side of the boundary.**
4. **magnetic inner product $\mathbf{0.000 \times 10^{0}}$** (Computation 3.1): **zero before averaging.**
5. **speed $\mathbf{0.911043357914 \to 0.911043357916}$** (Computation 3.1): **a change of 1.759×10^{-12}.**
6. **x component $\mathbf{0.700000 \to 0.559541}$** (Observation 3.3): **zero work, real influence.**
7. **storage growth $\mathbf{8.854187813 \times 10^{-8}}$ watts** (Computation 4.1): **the core.**
8. **ratio to side inflow $\mathbf{1.000000000000}$** (Observation 4.3): **the ledger closes to 12 digits.**
9. **$\mathbf{B}$ never appears in $\mathbf{J} \cdot \mathbf{E}$** (Observation 3.4): **the shape of the term.**

10. **the separator is which zero** (Observation 5.1): **three different predictions.**

11. **magnetic moments excluded** (Observation 5.6): **point charges only.**

Closing: **Electricity has three settings in which something is said to do no work.In the first, only the time average is zero——a pure inductor has mean power 1.004×10^{-17}, while the instantaneous power reaches 0.500000 and the r.m.s. current is 0.707107. The instantaneous power is $(1/2)\sin 2t$, at twice the frequency: energy crosses twice per period between source and inductor. Insert a series resistor of 1 and the mean becomes 0.250000, matching the closed form. The zero belonged to the circuit, not to alternation.In the second, the inner product itself is zero——the Lorentz force is orthogonal to velocity by definition, the peak normalised inner product is 0.000×10^{0}, and the zero holds before any average is taken. Still, the speed changes only from 0.911043357914 to 0.911043357916, a relative 1.759×10^{-12}, while the x component moves by 0.140459: zero work is not zero influence. In the ledger, $\mathbf{B}$ never appears in $\mathbf{J} \cdot \mathbf{E}$, though it does appear in $\mathbf{S}$ and in u, so it is absent from one term out of three.In the third there is no zero at all——with no free current in a capacitor gap, $\mathbf{J} \cdot \mathbf{E} = 0$, but nothing became zero: the quantity never lived there. The stored energy grows at $8.854187813 \times 10^{-8}$ watts and matches the Poynting inflow through the cylindrical wall with ratio 1.000000000000, so two terms close the account. Energy enters from the side rather than along the leads; what moves is field, not charge. This is a check and not a claim: omit the displacement current as a source and the inflow vanishes and the ledger stays open.The separator is which zero it is——the average zero breaks when the circuit changes, the inner-product zero breaks for no configuration, and absence from a term moves only if the ledger is rewritten. By the criterion of Paper 300, the first needs a period, the second does not, and the third is not a quantity, so the shared value zero is no evidence of a shared root. The direction is opposite to Paper 481: there a broken law could be blamed anywhere, while here the ledger fixes one destination.To be honest——the Poynting vector admits an added curl and localisation was not discussed; only the ledger integrated over a closed surface was used. Magnetic moments lie outside the frame, and the inner product is exactly zero only for a point charge. Power-factor correction was not treated, and no substance was given to the displacement current. What can be said is that three uses of "does no work" occupy three different places in one equation, and that confusing them changes what is predicted, and no further.**

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