

# Fluxions, Forces, and Fields

*An overview of the mathematisation of physics in Europe through the modern period*

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Zella Baig

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# Tracing Back

- Let's take a convenient starting point: Einstein, special relativity, & aether theory
- Much of the groundwork had been laid by Lorentz, with his *Theory of Corresponding States*<sup>1</sup>
- Much of the work Lorentz built on was done by George Fitzgerald, who was also influenced greatly by Maxwell

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<sup>1</sup>Janssen and Stachel, 2004.

# Beyond Maxwell

- 'Mentored' by William Thomson<sup>2</sup> (later Lord Kelvin)... who was a major figure in shaping physics (or natural philosophy) in C19
- Physics in Thomson's day had been centred around energy (and thus dynamics)...
- ... Which followed from continental development furthered by figures such as Lagrange and Laplace...
- ... Who worked using methods derived from Newton's work on celestial motion

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<sup>2</sup>Smith, 1978.

**Isaac Newton (1642-1727)**

# Newtonian Mathematical Ideals

- Saw God as mathematical, with a fondness for geometry<sup>ii</sup>
- Would have grown up with Cartesianism (deductive reasoning), but clashed with it later in life<sup>3</sup>

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<sup>3</sup>Westfall, 1981.

<sup>ii</sup>Newton's piety would greatly influence his work

# Experimental Philosophy

- The method of **resolution** & **composition**:
  1. Observe and “come to the general properties of things”<sup>4</sup>
  2. Assume said properties and describe further phenomena
- **Hypotheses non fingo**<sup>5</sup> - ignorance is acceptable!
- Nature able to be quantised (e.g. fluxional calculus & Halley’s Comet)
  - Concept of forces at a distance

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<sup>4</sup>Newton and McGuire, 1970.

<sup>5</sup>Newton, Cohen, et al., 1999.

# **The Dynamical Age: Continental Physics**

# Laplacian Physics

- The rise of French scientific dominance
- Physics spearheaded by Laplace in early C19, who took an "astronomical view of nature"<sup>6</sup>
- Prevalence of central-force based models, for even minute scales<sup>7</sup>
- Competitions set-up with e.g. the Society of Arcueil to promote mathematical collaboration
- Development of light, heat, and electromagnetic theory with various contestants (e.g. Fourier) - via Laplacian methods

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<sup>6</sup>Merz, 1896.

<sup>7</sup>Fox, 1974.



# Energy Physics

## William Thomson (1824-1907)

- Ideas of *vis-viva* around since Leibniz, *caloric* furthered by e.g. Carnot in early C19
- Natural philosophy shifted towards a focus on (conservation of) energy - in particular heat<sup>8</sup>
- Thomson follows Newtonian ideals - refusing to assign hypotheses
- There exist “absolute numerical relations” between heat and power<sup>9</sup>

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<sup>8</sup>Smith, 1978.

<sup>9</sup>Thomson, 1851.

**James Maxwell (1831-1879)**

# Electromagnetism

- Faraday had done groundbreaking work on electromagnetism, but almost entirely qualitative
- Maxwell reticent to attribute any physical cause; *Faraday's Lines*<sup>10</sup> makes no claim of physicality
- *Dynamical Theory*<sup>11</sup> made little note of aether as it was mathematically unnecessary
- *Physical Lines*<sup>12</sup> - first postulates light being electromagnetic, as well as displacement current

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<sup>10</sup>Maxwell, 1856.

<sup>11</sup>Maxwell, 1865.

<sup>12</sup>Maxwell, 1861.

# Maxwell & Vectors

- Greatly develops ~~vector~~ calculus out of necessity for his mechanical models - Maxwell didn't have vector notation at his disposal!
- Modern formulation only introduced in 1884, by Heavyside<sup>13</sup>
- Vector notation itself only introduced in 1843, by Hamilton<sup>14</sup>

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<sup>13</sup>Hunt, 2012.

<sup>14</sup>Crowe, 1994.

# **Aether Theory & Special Relativity**

# The First Cracks

- Following Maxwell's work, electromagnetism became dominant<sup>15</sup>
- The nature of the aether<sup>iv</sup> was hotly debated
- Lorentz develops ideas of 'local time' & 'corresponding states' (co-ordinate transforms - *but only of EM waves*<sup>16</sup>)

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<sup>15</sup>Hunt, 1994.

<sup>16</sup>Brown, 2005.

<sup>iv</sup>In fact, Newton's initial work necessitated a vacuum in space

# Henri Poincaré (1854-1912)

- Develops theory to be (functionally) identical to modern Lorentz transformations<sup>17</sup>
- Willing to ignore aether hypotheses, as mathematically unnecessary<sup>18</sup>
  - Unwilling to fully commit to ideas: “Of hypotheses there is never lack”<sup>19</sup>
- Einstein would soon go on to have his *annus mirabilis* and completely shift away from aether theory

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<sup>17</sup>Darrigol, 1995.

<sup>18</sup>Poincaré, Blondin, and Neculcea, 1901.

<sup>19</sup>Poincaré and Halsted, 1929.



## Conclusion

## To Sum Up...

- Initial shift with Newton's development of *experimental philosophy* and quantisation of nature
- Development of continental force-based physics
- Shift towards disciplinary rigour with Thomson and others
- Maxwellian development of electromagnetic theory
- The final steps away from the aether - after thousands of years

**Thank You**

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