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THE MATERIALS JOINING EXPERTS

Lord Rayleigh – Also a Founder of High Power Ultrasonics*

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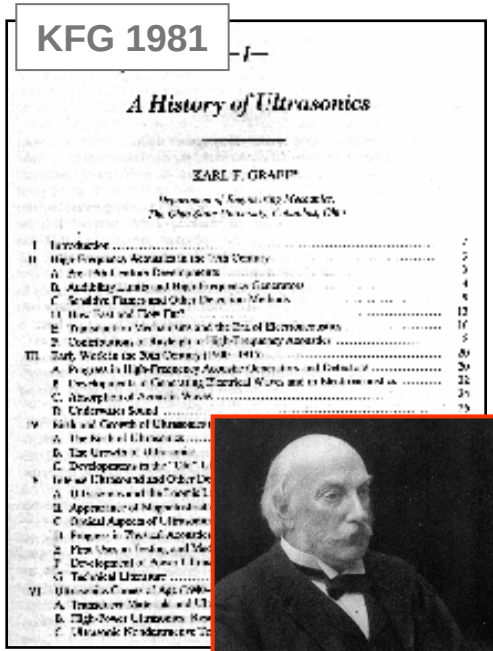
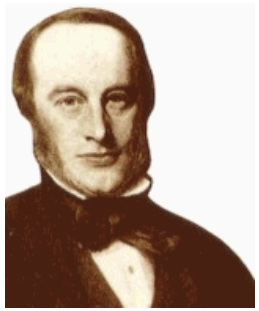
*Originally intended for UIA 2007

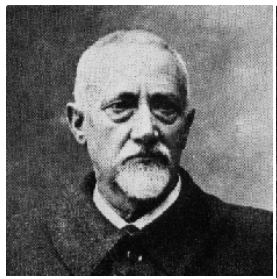
“A History of Ultrasonics”

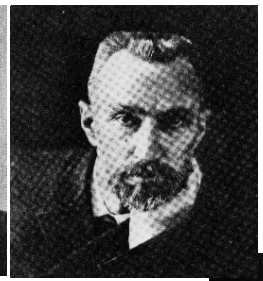
KFG 1981

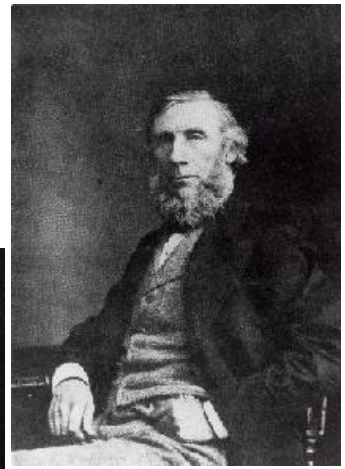

A History of Ultrasonics

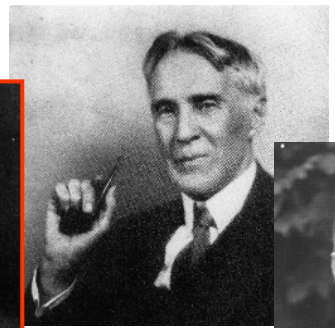
KARL F. GRAFF*

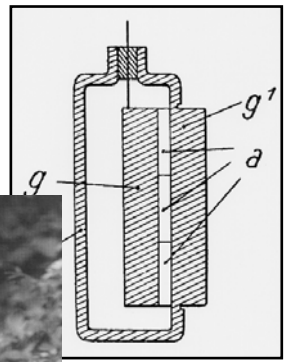


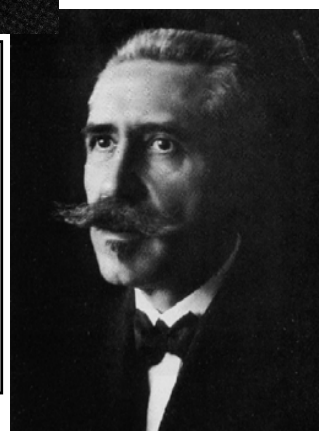


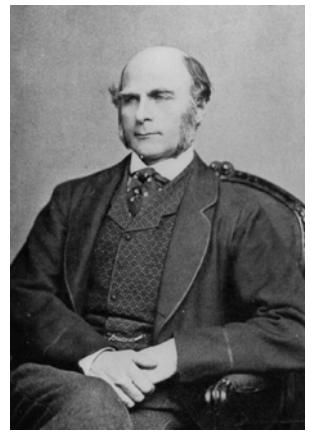


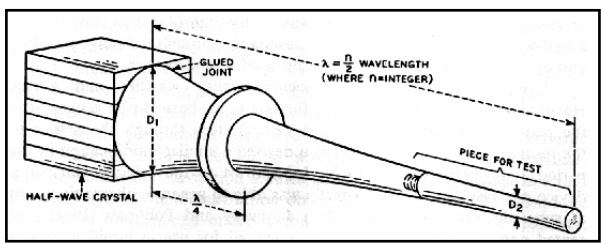


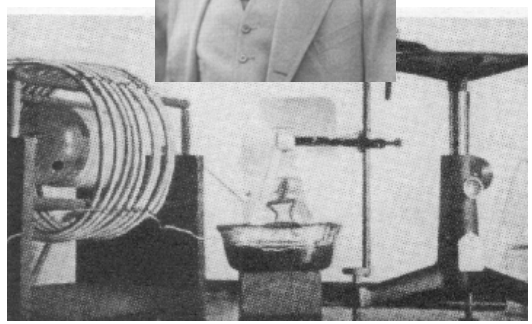


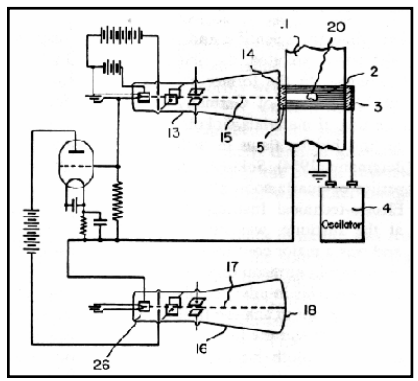












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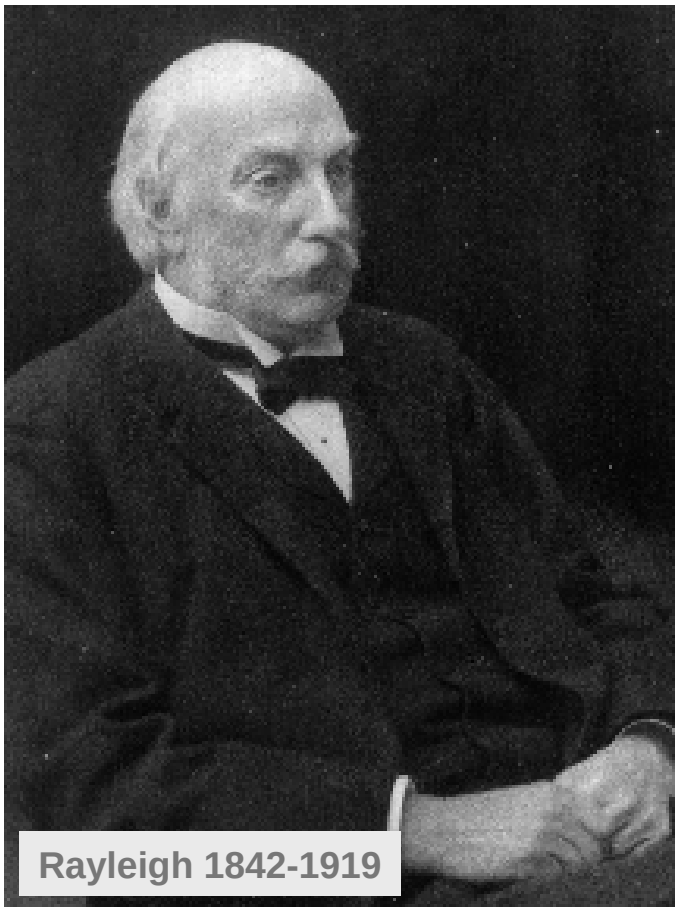
From “History” … Noted …



Rayleigh 1842-1919

A “Giant” of acoustics … contributions to ultrasonics … cavitation, atomization, surface waves …

Importance to our field ranks as a true “Founder” and merits greater attention to the “Life of Rayleigh”

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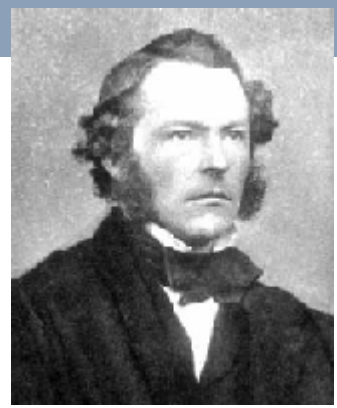
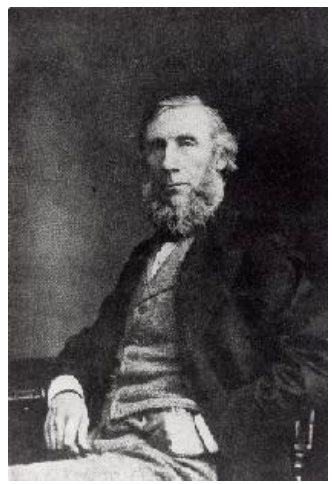
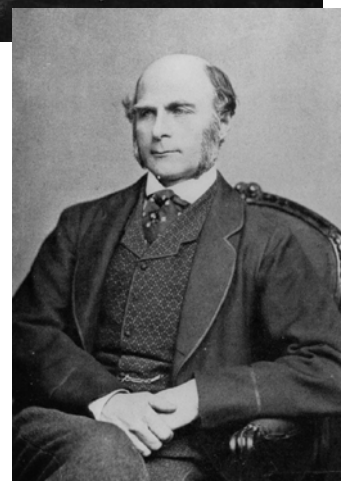
John William Strutt – Early Life,

- Born – 1842: Sickly, slow to speak – ‘That child will either be very clever or an idiot’
- Cambridge - Stokes lectures, ‘Senior Wrangler’ 1865; Fellow of Trinity College 1866; visited US
- Helmholtz, Tyndal, Galton had influence
- “Theory of resonance” 1871 – made early reputation
- Noted lack of comprehensive acoustics book







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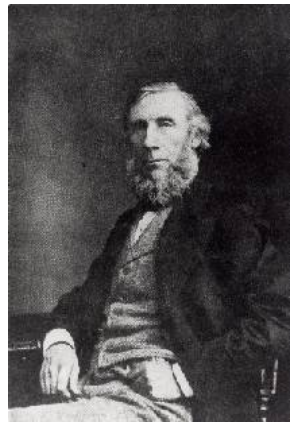
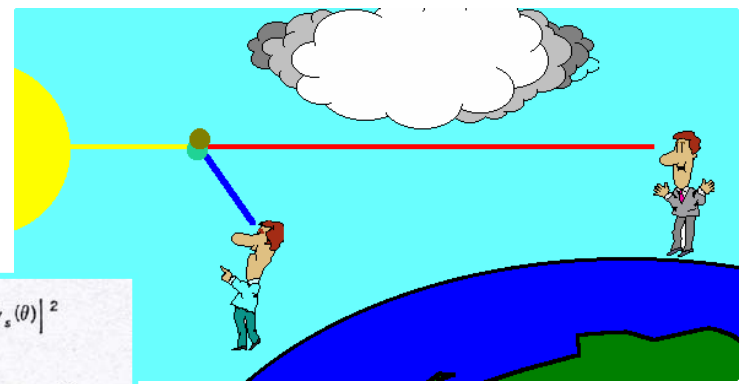
Why is the Sky Blue?

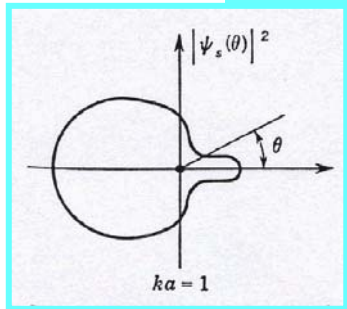
- Among earliest publications – noted work of Tyndall – “colour due to particles that divert light from its regular course”
- Explained light scattering for case of λ >> d (wavelength much greater than scatterer)

$$I \sim I_0/\lambda^4$$

- Inverse fourth power law – “Rayleigh Scattering” – explains blue of sky and red of sunset
- Finds wide application in radar, sonar and ultrasonics







“On the Light from the Sky, its Polarization and Colour,” Phil. Mag. Vol. XLI, pp. 107-120, 274-279 (1871)

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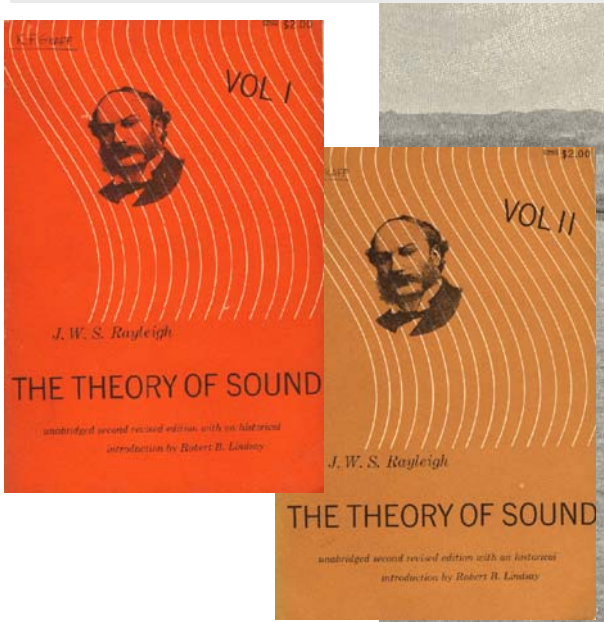
Acoustics on the Nile

Rheumatic fever – 1872 Winter in Egypt



Published 1877

(Dover 1945)

“Principia of Acoustics”

Stoddard’s Lectures, V. II, Constantinople, Jerusalem, Egypt, 1897, p. 285, dahabiyeh; dahabeah

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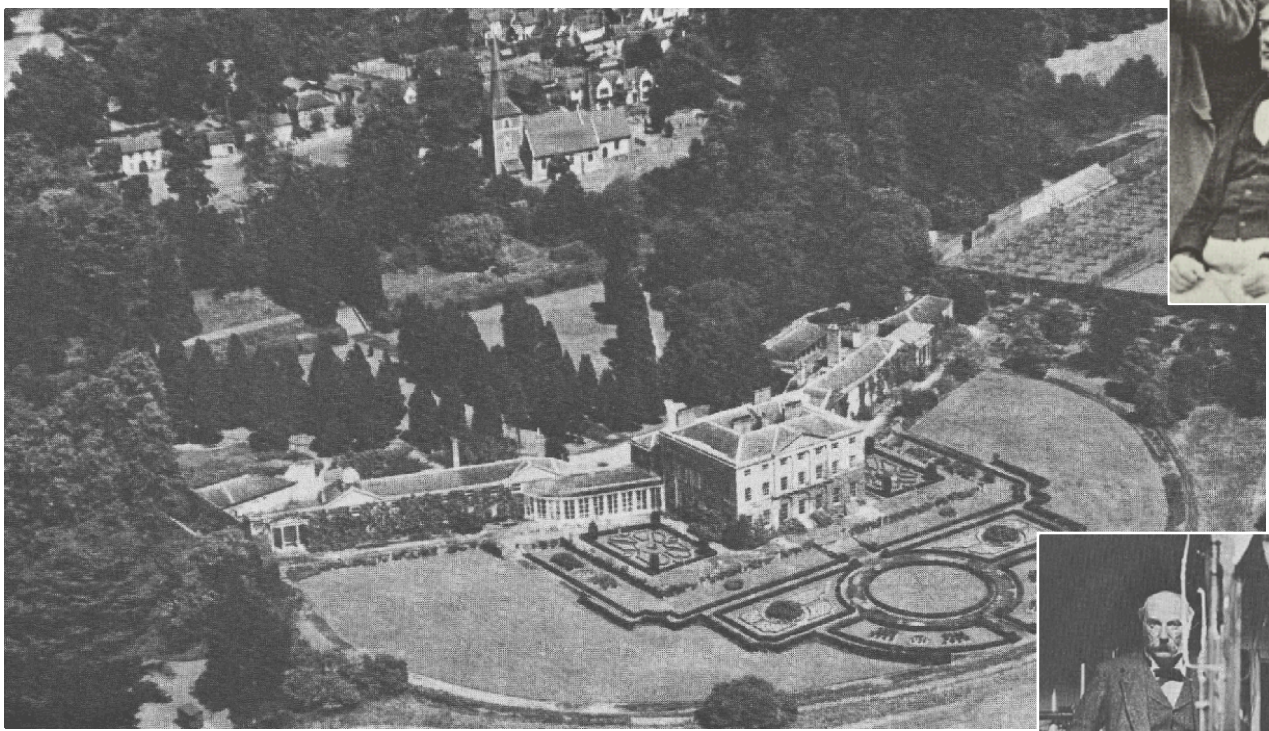
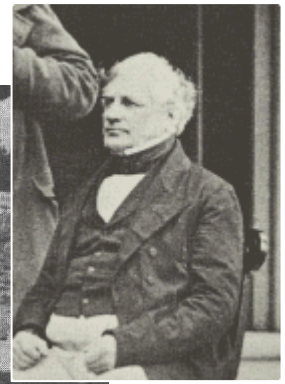
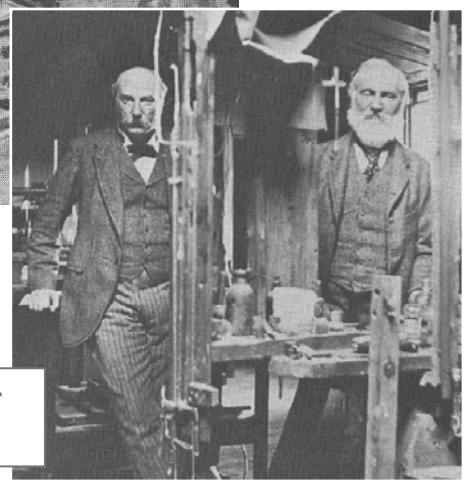
Third Baron Rayleigh 1873

- Death of father 1873







Terling – 7000 acres

Kelvin – “things held together with tape and wire”

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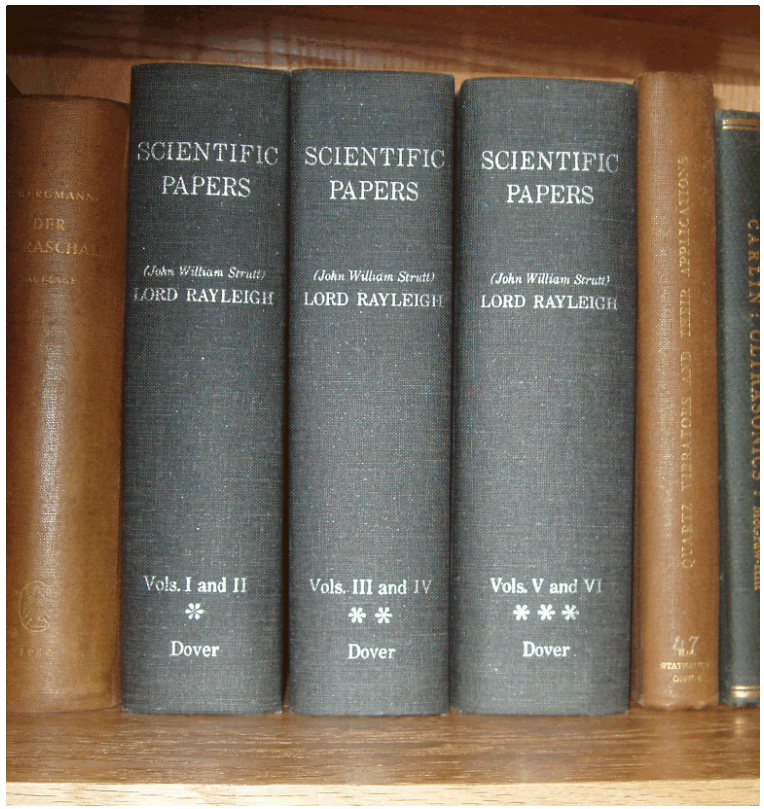
Collected Works

- Lifetime contributions enormous – 446 papers – covered every field of physics known in his day – optics and acoustics dominate
- Exception – evolving atomic physics
- Special to ultrasonics …
  - Cavitation
  - Atomization
  - Surface waves
  - Molecular acoustics
  - Acoustic pressure
  - Finite amplitude waves
  - Streaming



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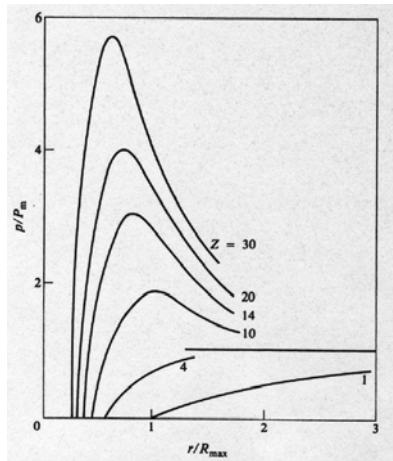
Contributions … Cavitation

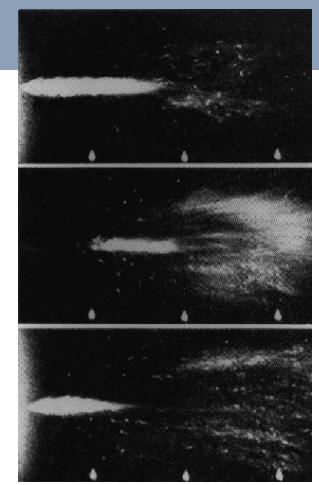
- Cavitation – sonoluminescence – most widely studied US field
- Interest in phenomenon arose from poor performance of new British warships (1896) – traced to propeller (hydrodynamic) cavitation
- Rayleigh interest – first in tea kettles – became aware of propeller problem
- Used energy methods to arrive at classical result …

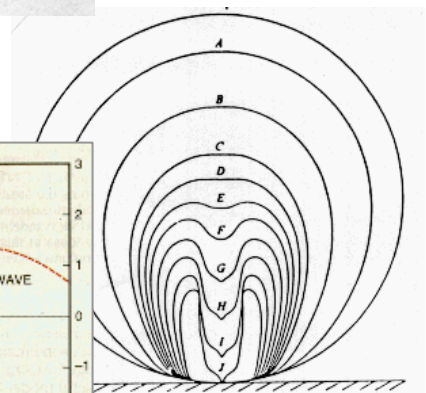
$$d(UR^2)/dt = 2RU^2 - (P/\rho)(R_0^3/R^2)$$

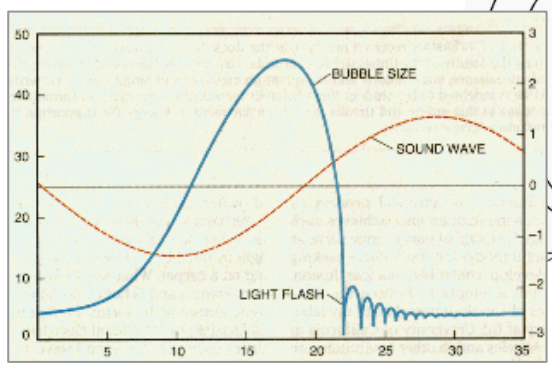
$$U = dR/dt$$



Neppiras, 1980







"On the Pressure Developed in a Liquid During the Collapse of a Spherical Cavity," Phil. Mag. Vol. xxxiv, pp. 94-98 (1917)

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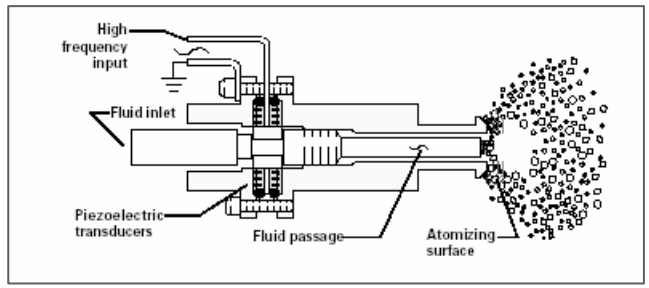
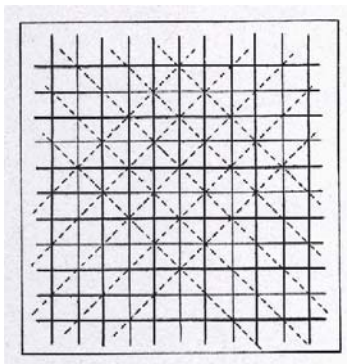
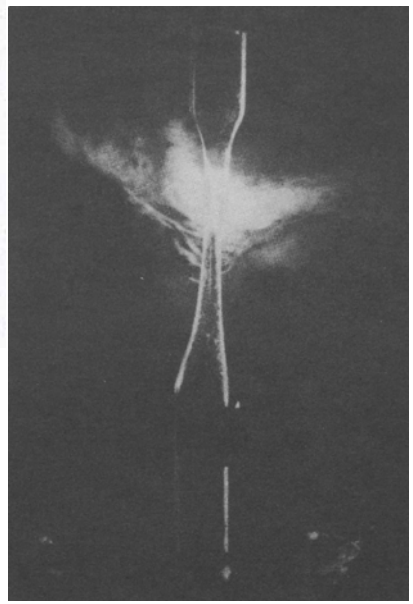
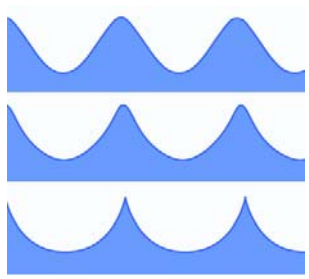
Atomization

- US atomizers, nebulizers widely used today in industry, medicine
- US production of sprays, fogs noted by Wood & Loomis, 1927
- Rayleigh provided first analysis of “crispations” – expression for λ and noted parametric nature of wave frequency
- Threshold for unstable waves, droplet formation by others









“On the Crispations of Fluid resting upon a Vibrating Support,” Phil. Mag. Xvi, pp. 50-58, 1883

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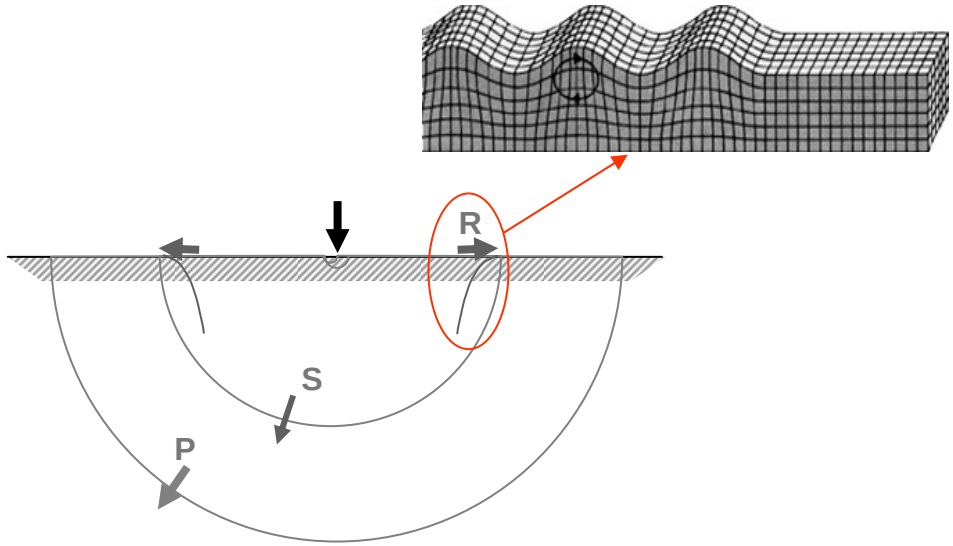
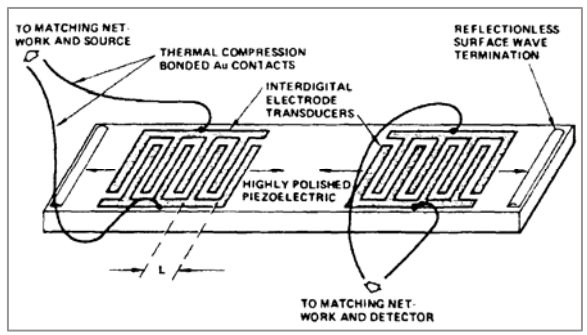
Surface Waves

- Showed 3rd type of wave to P and S waves (carrying 2/3 of energy)
- "It is not improbable that the surface waves here investigated play an important part in earthquakes … diverging in two dimensions only, they must acquire at a great distance from the source a continually increasing preponderance."





"On Waves Propagated Along the Plane Surface of an Elastic Solid," Proc. London Math. Society, XVII, pp. 4-11 (1885)

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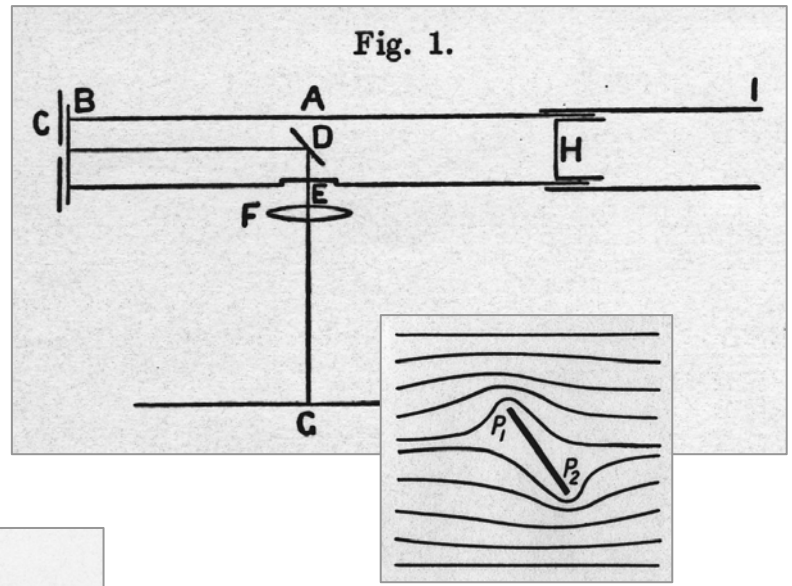
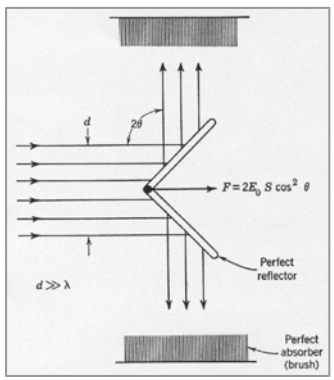
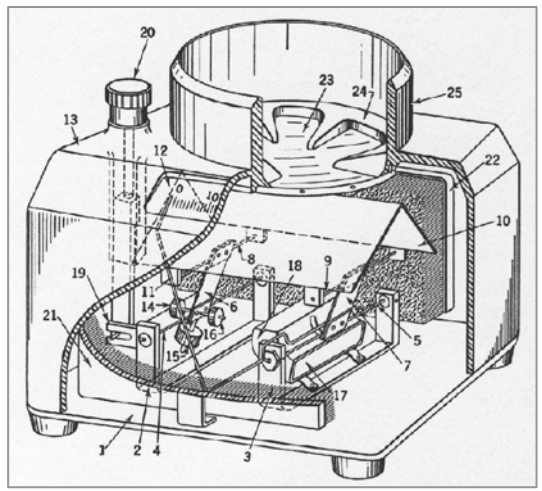
Sound Intensity, Radiation Pressure

- Noted galvanometer sensitivity to air disturbance – led to “Rayleigh Disc” for sound intensity
- Noting light waves were found to exert pressure – led to prediction of acoustic pressure (a 2nd order effect) – and to means of measuring acoustic power*







“On an Instrument Capable of Measuring the Intensity of Aerial Vibrations,” Phil. Mag., XIV, pp. 186-187, 1882.

“On the Pressure of Vibrations,” Phil. Mag. III, pp. 338-346, 1902.

* … and to need for later distinguishing of “Rayleigh” and “Langevin” pressure

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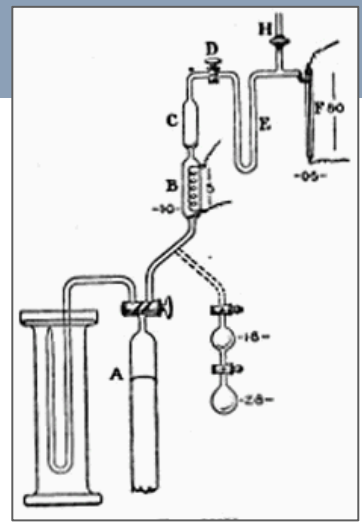
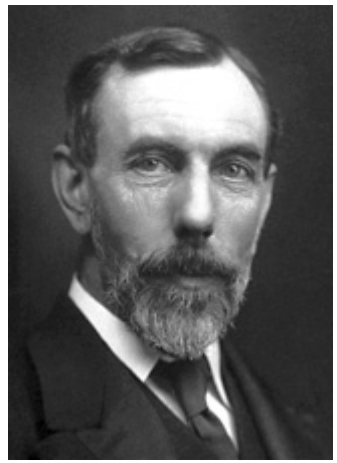
Discovery of Argon

- Rayleigh known at “Wikipedia” level as recipient – with Ramsey – of 1904 Nobel prizes for discovery of Argon
- In studying gas densities he found that N density varied by method of preparation – ‘physical’ N derived by absorbing O, CO_2 and H_20 from atmospheric air was 1/1000 heavier than ‘chemical’ N derived from ammonia.
- Painstaking experiments by Rayleigh and Ramsay (who was pursuing parallel work) led to conclusion (1894) that the atmosphere contained a new constituent – named Argon (from Greek “argos” – idle)
- Required a complete rethinking of the periodic table (since Ramsay went on to isolate other Noble gases, He, Ne,…)





Sir William Ramsay

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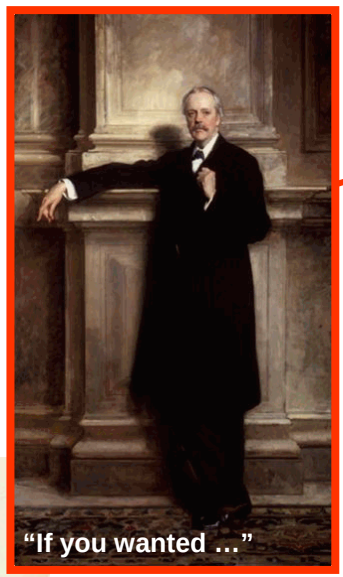
NPL, Cambridge

- Rayleigh led fight for NPL
- Cambridge Chancellor – 1908
- Powerful friends

1902 Opening Ceremony – with Prince & Princess of Wales

Installation of Lord Rayleigh as Chancellor of Cambridge University, June, 1908. To the right are seen Mr. Asquith, the Duke of Northumberland, Lord Halsbury, and Sir John Fisher (the latter in uniform).



"If you wanted …"

Robert John Strutt, Arthur Balfour, and Lord and Lady Rayleigh, on the occasion of Robert's coming of age, 1896.

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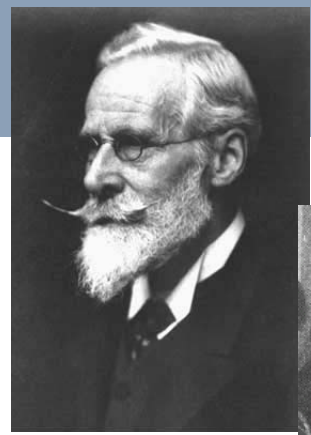
Psychical Interests – "Skeleton in Rayleigh Closet?"

- With stimulus of Crookes – Rayleigh became interested in psychical phenomena (aka 'spiritualism') in 1870's
- Nearly last public address was to SPR* - unconvinced to the end … "if thoughts can move a heavy table – how can we trust our laboratory balance to 1/10 milligram?"
- His interests carried forward by his son and biographer



Sir William Crookes
1832-1919

Robert John Strutt,
4th Baron Rayleigh

Conan Doyle, Houdini

* "Presidential Address to the Society for Psychical Research," Proc. of the Soc. For Psychical Research, Vol. xxx, pp. 275-290 (1919)

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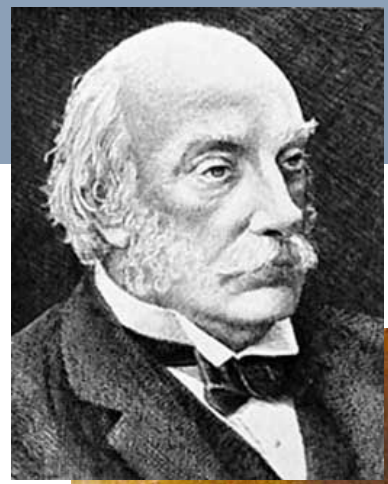
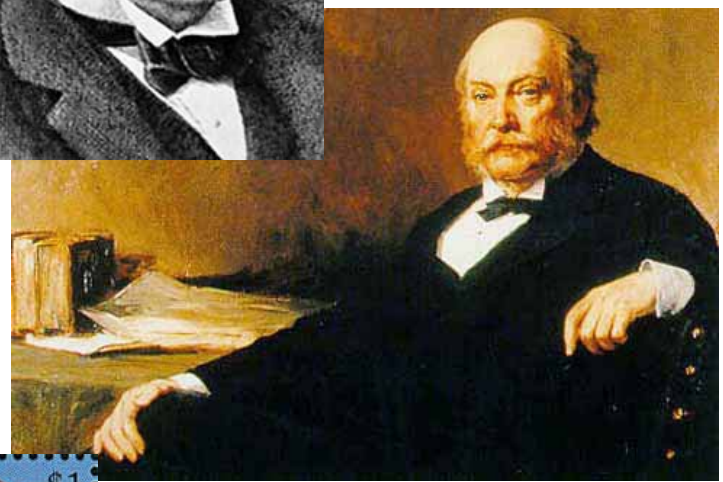
… “and many more”

- While Rayleigh’s works were to have major impact in US, he did not evidence direct interest in high-frequency acoustics as a field of study *per se*.
- Yet he made frequent use of such devices as whistles and the sensitive flame to illustrate acoustical phenomena – his many studies of acoustic diffraction and radiation were implicitly directed at high-frequency phenomena.
- Work bridged 19th and 20th centuries – his contribution to bubble collapse, two years before his death in 1919, occurring at the very birth of modern ultrasonics.

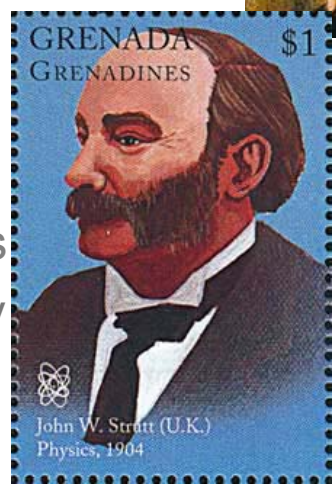
Rayleigh Today





Additional to surface waves, etc, have … Rayleigh …

- … (probability) distribution
- … criterion (optics)
- … number (convection in fluid mechanics) – Rayleigh-Benard convection cells
- … quotient iteration, Rayleigh-Ritz method
- … fading simulation
- … -Jeans (blackbody) distribution
- … -Taylor instability – fluid dynamics
- … -Schrödinger Perturbation Theory
- … streaming, etc, etc



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Questions?

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