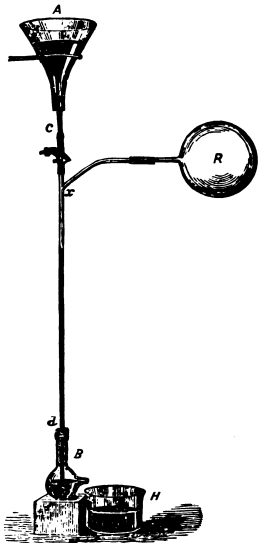
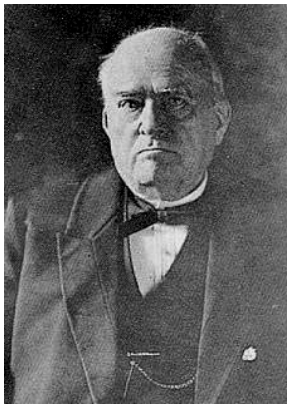
1861 – 1871

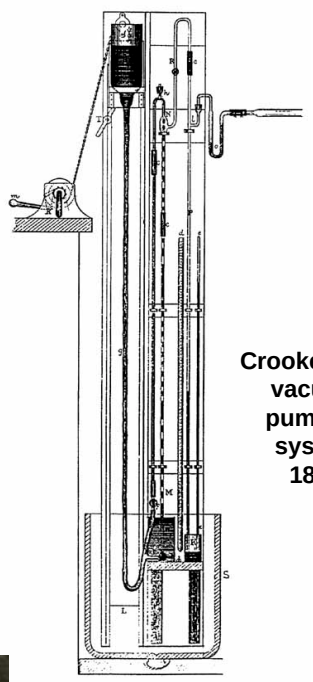


Sprengel mercury drop pump 1865

Hermann Johann Philip Sprengel (1834-1906)



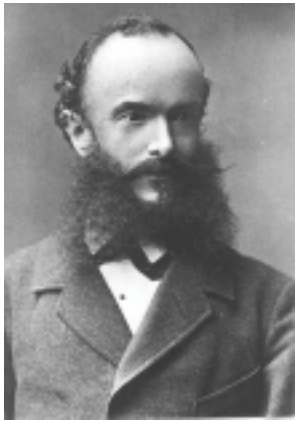
Johann Wilhelm Hittorf (1824-1914) Demonstrates that cathode rays travel in straight lines, develops Hittorf tube 1869



Crookes high vacuum pumping system 1870

William Crookes (1832-1919) Suggests that cathode rays are negatively charged particles 1871

Cromwell Fleetwood Varley (1828-1883) Suggests that cathode rays are particles 1871



August Töpler (1836-1912)

Geissler-Töpler Mercury vacuum pump 1862

Johann Josef Loschmidt (1821-1895) Estimates diameter of molecule from kinetic theory of gases 1866

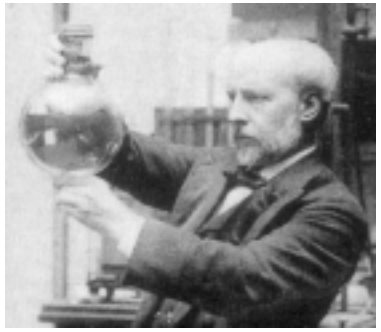
F. M. and P. H. Roots Industrial Roots Blower Pump 1868

Robert Wilhelm Bunsen (1811-1899) Water jet vacuum pump 1870

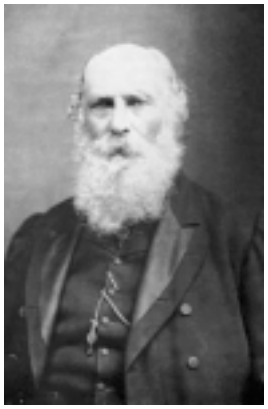
Scientific American

Alfred Ely Beach Builds block-long pneumatic subway in New York City 1870

1872 – 1878

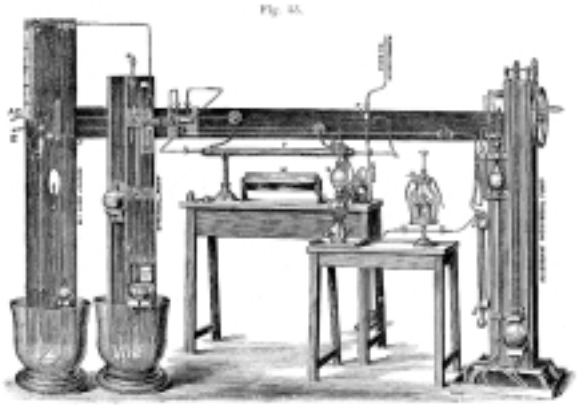


James Dewar
Describes precursor of the dewar thermos vacuum flask
1872-1873

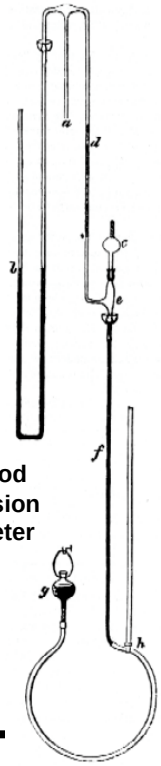


George Johnstone Stoney
(1826-1911)
Estimates the charge on cathode ray particles (electrons)
1874

Warren De La Rue
(1815-1889)



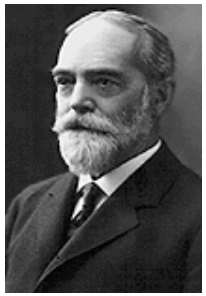
Warren De La Rue and Hugo W. Müller
Studies of direct-current glow discharges in various gases
1878



Herbert G. McLeod
Volume compression mercury manometer
1874

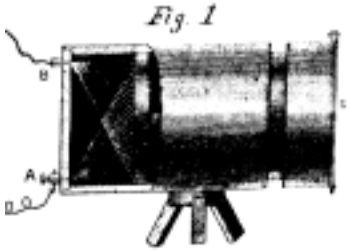
Lambert von Babo
(1818-1899)
Self-recycling Sprengel pump
1876

William Crookes
Pumping by chemical getters
1876



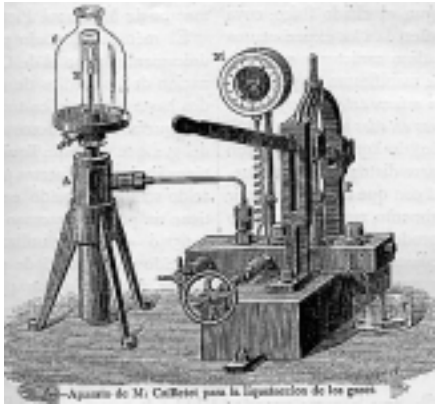
Yale Medicine

Arthur W. Wright
Describes thin film deposition by arc vaporization
1877



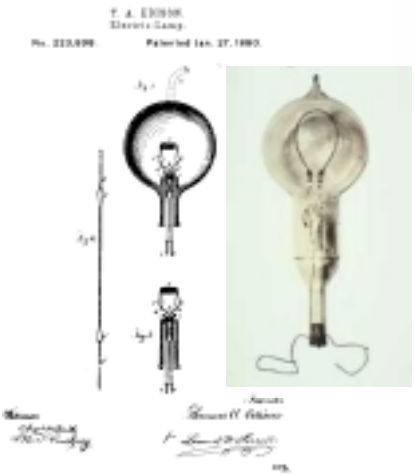
George R. Carey
Selenium photoelectric cell
1874

Eugen Goldstein coins the term *Kathodenstrahlen* (cathode rays)
1876

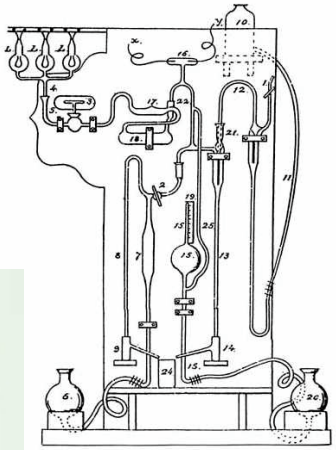


Louis Paul Cailletet
(1832-1913)
Liquifies oxygen, hydrogen, nitrogen, and air - Invents altimeter and high-pressure manometer
1877-1878

1879 – 1886



Thomas Alva Edison
(1847-1931)
Files U. S. patent on high vacuum carbon-filament incandescent lamp
1879

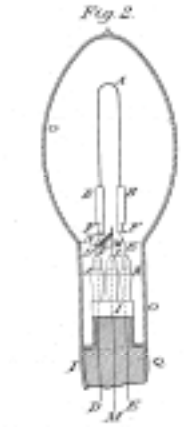


Vacuum apparatus for exhausting Edison's electric lamps - based on Crookes' design
1879-1880

William Crookes
Invents the Crookes tube, early form of the cathode ray tube
1879

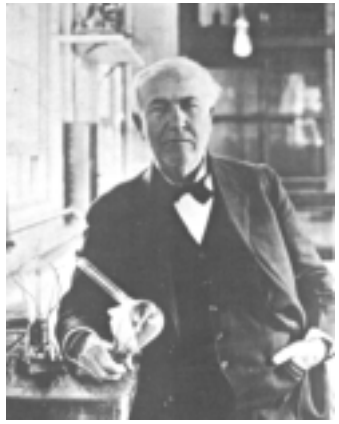
Thomas Edison
forms the
New York Edison
Illuminating Company
1880

General Electric Company formed by merger of Edison General Electric and Thomson-Houston Co.
1882



Desmond G. Fitz-Gerald
Patents integral magnesium getter for an incandescent lamp in England (1881) and U. S. (1883)
1881

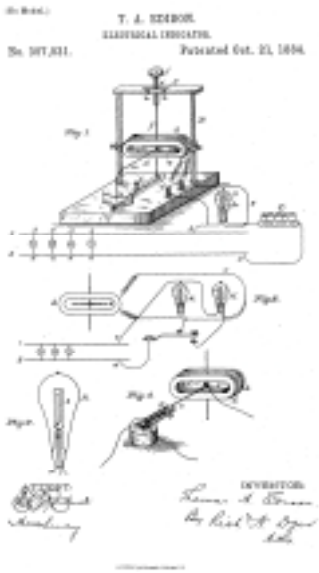
John Ambrose Fleming
(1849-1945)
Presents a paper on the "*molecular shadow*" to the Physical Society of London
May 26, 1883



Edison with 'Edison Effect' bulb

Edison observes thermionic emission in vacuum
March 1883

Edison files patent on thin film deposition by thermal evaporation in a vacuum
1884



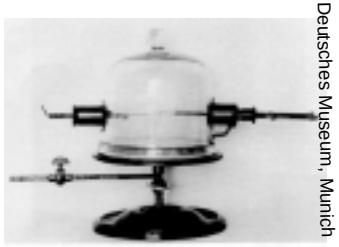
Edison Effect
Electrical Indicator
U.S. Patent 307031
1884

William Preece
Duplicates Edison's thermionic emission experiment, makes quantitative measurements, and presents results to Royal Society
March 26, 1885

American Institute of Electrical Engineers holds first meeting during the Philadelphia International Exhibition
1884

Eugen Goldstein
Observes *canal* rays (positive ions), so called because they bored holes in a discharge tube cathode
1886

1887 – 1895



Heinrich Rudolph Hertz
(1857-1894)
Discovers
photoelectric effect
1887

Henry A. Fleuss
Oil Piston Pump
1892

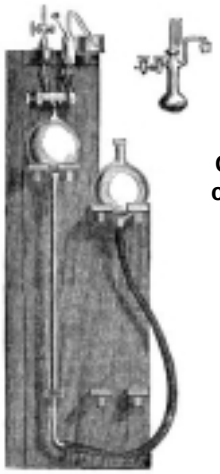
Heinrich Rudolf Hertz
(1857-1894)
Discovers cathode
rays can penetrate
thin metal sheets
1892

George J. Stoney
Suggests the name
electron **for cathode**
ray particles
1891

Wilhelm Conrad Röntgen
(1845-1923)
Discovers x-rays
December 1895

Jean-Baptiste Perrin
(1870-1942)
Proves cathode rays
are a stream of
charged particles
1895

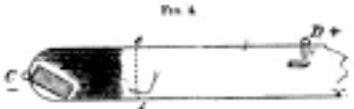
Philipp E. A. Lenard
(1862-1947)
Added to Hertz's work on
cathode rays penetrating
thin metal sheets
to study and map
magnetic fields
1894



Geissler-Friedrichs
mercury
vacuum pump
1887

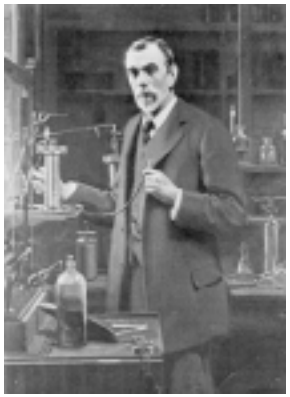
Crookes Maltese
cross experiment
1887

Albert Hess
Uses Lenard tube
to study and map
magnetic fields
1894



William Crookes
Studies "Electrical Evaporation"
(sputtering)
"The process has been much
used for the production of small
mirrors for physical apparatus."
1891

Jonathan Zenneck
Improves Braun's cathode
ray tube and adds time
base deflection
1889



William Ramsay
(1852-1916)
Isolates argon from air
1894

James Dewar
(1842-1923)
Cryogenic pumping with
liquid air cooled charcoal
1892
Liquefies hydrogen
1898

Guglielmo Marconi
Transmits a
wireless signal for
one mile
1895

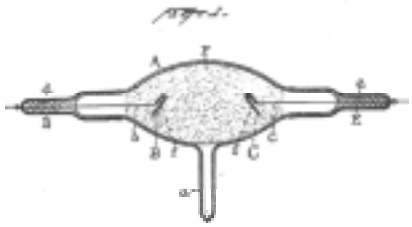
Stokes Vacuum
founded
1895

1896 – 1899

J. A. Fleming reports to the Physical Society of London that his "lamp" functioned as a rectifier
March 27, 1896

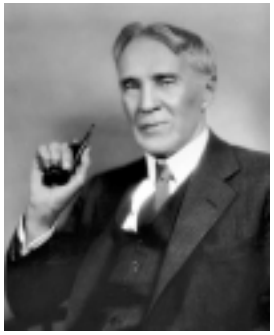
Daniel MacFarlan Moore Devises a white light illumination system using carbon dioxide gas discharge tubes 1-3/4" in diameter and up to 200 feet long
1896

Malignani Corp. (Italy) Production use of chemical gettering by phosphorus
1896

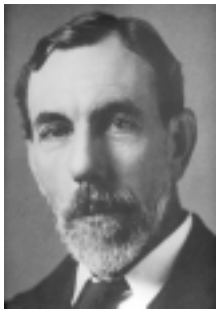


Edison files patent on precursor of the fluorescent lamp and fluoroscope
1896

Joseph John Thomson (1856-1940) Discovers the electron (he called them *corpuscles*)
1897



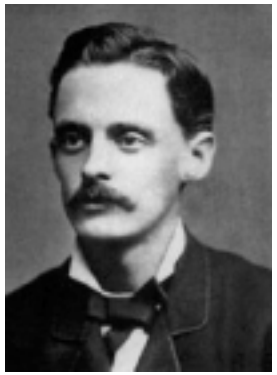
Robert Williams Wood (1868–1955) Demonstrates field emission of electrons from a metal into a vacuum
1897



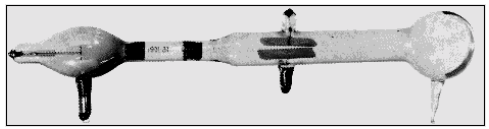
William Ramsay (1852-1916)

Morris William Travers (1872-1961)

Discover neon
1898

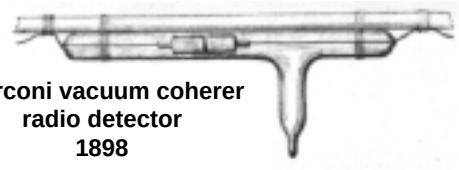


Elihu Thomson (1853-1937) Commercial medical x-ray machines
1896



Karl Ferdinand Braun (1850-1918) Cathode Ray Tube
1897

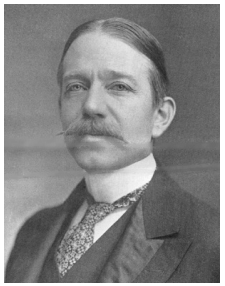
William Sutherland (1859-1911) Gas-viscosity laws
1897



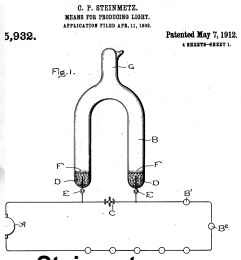
Marconi vacuum coherer radio detector
1898

1900 – 1905

W. C. Roentgen
Nobel Prize in Physics
for discovery of x rays
1901

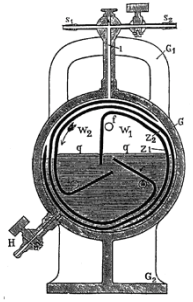


Peter Cooper Hewitt
(1861-1921)
Fluorescent lamp
1901
Mercury vapor lamp
1902

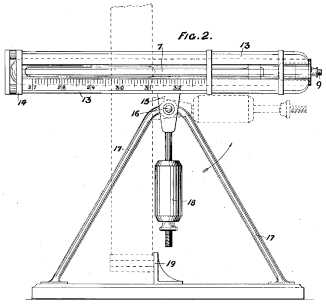


Charles Proteus Steinmetz
(1865-1923)
Mercury vapor lamp with halide
salts to improve color
U.S. Patent 1025932 (1912)
filed 1902

Lord Raleigh (John William Strutt)
(1842-1919)
Nobel Prizes in both Physics
(Discovery of argon) and
Chemistry (Studies of inert
gaseous elements in air)
1904



Max Paul Wolfgang Gaede
(1878-1945)
Rotary mercury-sealed
mechanical vacuum pump
1905



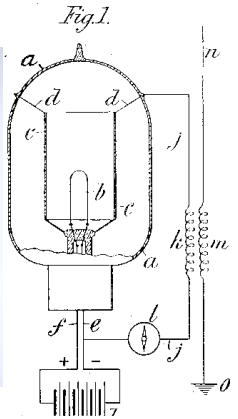
Arthur S. Davis
Portable tilting mercury
barometer – Forerunner of the
tilting McLeod gauge
U.S. Patent 676178 (1901)
filed 1901

E. Weintraub
Mercury vapor
arc lamp and rectifier
1902

Reginald Aubrey Fessenden
(1866-1932)
Patents heterodyne wireless
signaling
U.S. Patent 706740 (1902)
filed 1901

Harris J. Ryan
Magnetic deflection
cathode ray tubes
1903

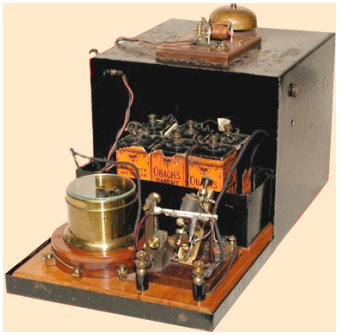
Guglielmo Marconi transmits
a wireless signal from England
to St. Johns, Newfoundland
1901



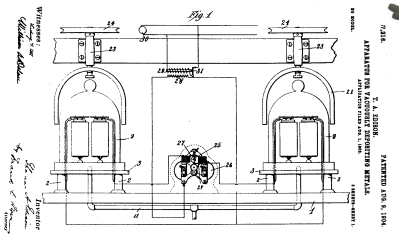
Detection of radio waves
with Fleming diode rectifier -
the first practical electron tube
U.S. Patent 803684 (1905)
filed 1905

General Electric Research
Laboratory Established
1900

Georges Claude
(1870-1960)
First neon lamp
c. 1902



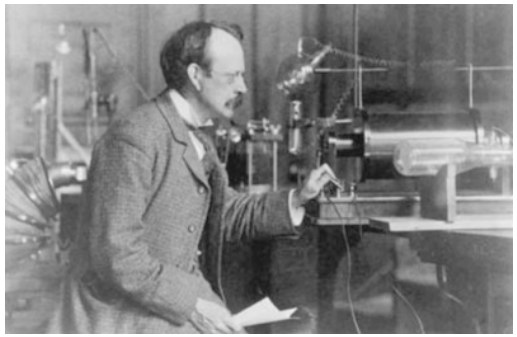
Marconi radio receiver
1898–1905



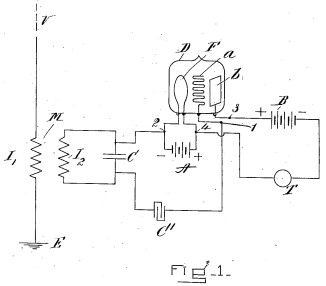
Edison's National Phonograph Co.
uses sputter coating to produce
phonograph cylinder masters
1903

1905 – 1909

Philipp Eduard Anton von Lenard
(1862-1947)
Nobel Prize in Physics for
cathode rays
1905



J. J. Thomson
Nobel Prize in Physics
Conduction of electricity through gases
1906



DeForest Space Telegraph
U.S. Patent 879532 (1908)
filed January 1907

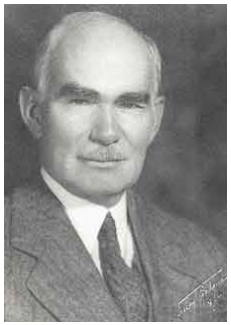
Max Dieckmann, Gustav Glage,
Boris L. Rosing and
A. A. Campbell Swinton
Propose the use of the Braun tube to
display television images
1906-1911

Guglielmo Marconi and
Carl Ferdinand Braun
Nobel Prize in Physics for
wireless telegraphy
1909

Kamerlingh Ohnes
(Netherlands)
Liquefies helium
1908

Jean B. Perrin
Estimates value of
Avogadro's number
(and coins name)
1909

Otto Von Baeyer
Triode ionization
vacuum gauge
1909

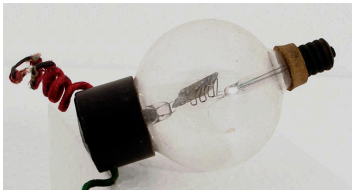


Lee de Forest
(1873-1961)

William David Coolidge (above)
(1873-1975) and Colin G. Fink
Develop ductile tungsten-filament
light bulb
1908-1910

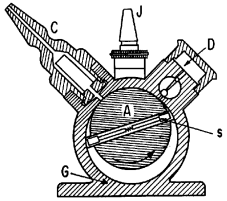
Marcello Stefano Pirani
(1880-1968)
Pirani vacuum gauge based
on thermal conduction from
a heated filament
1906

W. Kaufmann
First rotary vacuum pump
– a helical Torricelli tube
turned by an
electric motor
1905



De Forest *Audion* triode
1906

Arthur R. B. Wehnelt
Oxide-coated hot cathode
cathode ray tube
1907-1908



Gaede oil-sealed
vacuum pump
1907

First regular radio broadcast service
San Jose, California
Charles David Herrold (1875-1948)
1909

W. Voege
Thermocouple
vacuum gauge
1906

R. A. Fessenden
First public voice
radio broadcast
1906

Poulsen Wireless/
Federal Telegraph Co.
founded
1909

1909 – 1913

Robert A. Millikan (1868-1955)
and Harvey Fletcher (1884-1981)
Measure charge on the
electron (oil-drop experiment)
1909-1912

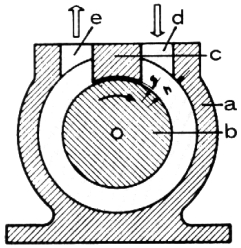
Martin Hans Christian Knudsen
(1871-1949), Denmark
Radiometer effect
vacuum gauge
1910

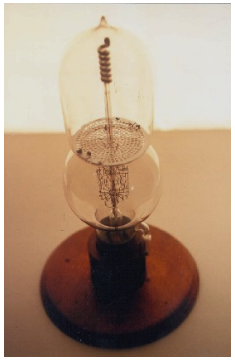
Levitt Luzern Custer
(1888-1962)
Statoscope aneroid
barometer
U.S. Pat. 1023132
(1912)
filed December 1909

de Forest Type RJ4 Audion detector
c. 1910-1914

Wolfgang Gaede
(1878-1945)

First theory and
experiments on
molecular-drag
pumping
W. Gaede
1912

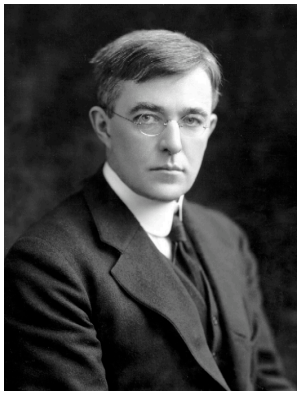




Telephone
relay tube,
Germany
(Leiben-Reiz)
c. 1910

Pfeiffer Co.
Rotary oil-sealed
mechanical
vacuum pump
1910

Georges Claude
Demonstrates neon
lamp in public
1910



Irving Langmuir
(1881-1957)
Surface and Vacuum
Science pioneer

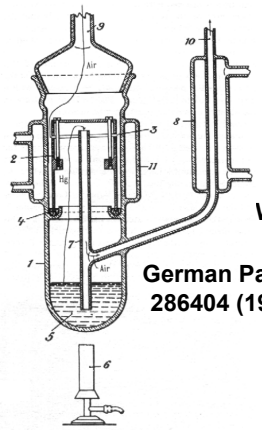
Gas filled
incandescent lamp
1912-1913

Edwin H. Armstrong
Regenerative circuit
1911

R. A. Fessenden
Heterodyne receiver
1912

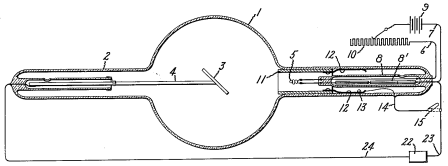
Saul Dushman
40 kV vacuum rectifier
1913

Lee de Forest
Vacuum
tube amplifier
1912



First mercury
diffusion pump
Wolfgang Gaede
1913

German Patent
286404 (1913)



William D. Coolidge
Vacuum tube for generating x rays –
often still called the Coolidge tube –
made x rays for medical diagnosis
safe and convenient
U.S. Patent 1203495 (1913)

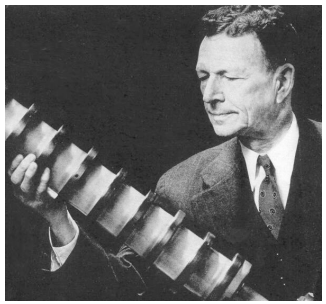
John B. Johnson
and H. J. Van der Bijl
First commercial
cathode ray tube
(Western Electric 224-A)
1913

A. Dufour
Cathode ray oscillograph tube –
a high-voltage continuously
pumped cathode ray tube that records
directly on photographic plates
1913

1914 – 1916

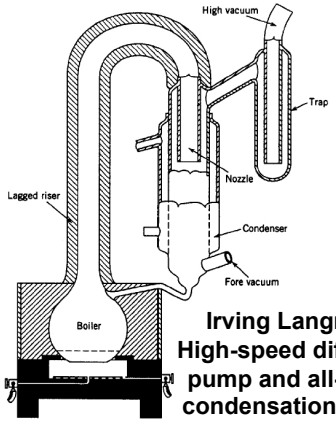
Max von Laue
Nobel Prize in Physics
for x ray diffraction
from crystals
1914

William Henry Bragg
and son, WIlliam Lawrence Bragg
Nobel Prize in Physics
for crystal structure derived
from x ray diffraction
1915



William D. Coolidge
Commercial x ray tube
1915

Oliver Ellsworth Buckley
(1887-1959)
Hot cathode
"ionization manometer"
high vacuum gauge
1916



Irving Langmuir
High-speed diffusion
pump and all-metal
condensation pump
1916

Thermocouple vacuum
gauge heated by an
externally-produced
beam of light
W. Rohn
1914

Edison & Swan Co.
Produces round valves
and Fleming valves
for Marconi Co.
in Great Britain
1915

Western Electric
Patents indirectly
heated cathode
1915

Tubular Audion developed
by Cunningham (October 1915)
and
Lee de Forest (April 1916)

Thomson Houston Co.
(England) begins production
of triodes including "R"
valve for military for
Marconi Co. in Great Britain
1916

McCandless Lamp Co
Produces tubes for de Forest
Triode – Acquired by
Westinghouse in 1914

Western Electric
begins production
of biased tubes for
American Telephone &Telegraph
starting with Type M/ 101A
1915

AEG-Telefunken (Germany)
Standardized radio receiving tubes
(EVN94, EVN129)
1914

Osram-G. E.
Start production of "R"
valves in Great Britain
1916

Marconi files suit
against de Forest
re triode
1914

General Electric begins
production of
Pliotron triode
1915

Vacuum concentration used
to preserve lime juice as
scurvy preventative
c. 1914

GE Tungar rectifier
December 1915

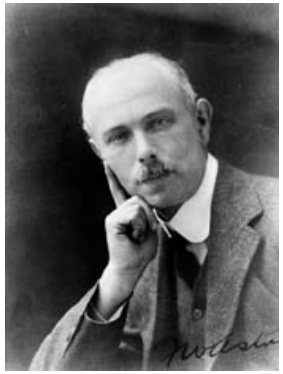
Telephone call using
Western Electric
triode amplifiers
1915

Irving Langmuir
Gas-filled
incandescent lamp
1915

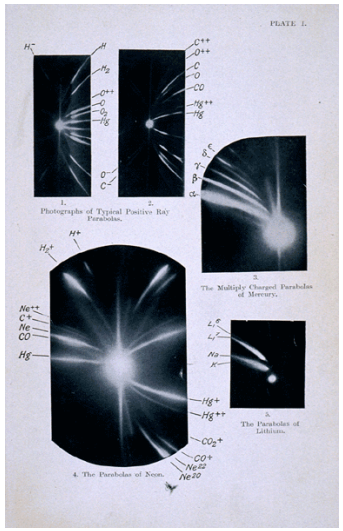
Siemens & Halske Co. (Germany)
Develops Type "A" vacuum tube
— about 50,000 produced
1916

1917 – 1921

Arthur Jeffrey Dempster
(1886-1950)
Mass spectrometer
1918



Francis William Aston
(1877-1945)
Mass spectrograph
1919



Edwin Howard Armstrong
(1890-1954)
Superheterodyne receiver
1920

Albert Einstein
(1879-1955)
Nobel Prize in Physics
for photoelectric effect
1921

Albert W. Hull
(1880-1966)
Magnetron tube
1917

IEEE

H. F. Stimson
Two-stage mercury
diffusion pump
1917

Fritz Lowenstein
Negative bias patent
1,231,764— July 3, 1917

American Telephone & Telegraph
purchases patent rights for
triode from de Forest
– de Forest retained rights for
amateur and experimental use
March 1917

Lee de Forest Radio Telephone &
Telegraph Co. manufactures
VT-21 and CF-185 tubes
for the U. S. Government
1917

GE produces YB-1
1918

Moorhead Laboratories,
San Francisco begins
production of SE-1444
for U. S. Navy – 50,000
per month claimed
1918

Western Electric develops
VT-1 and VT-2
for Signal Corps
Goes into high production
1917

AEG produces 250 RE11's
per day for war effort
in Germany
1918

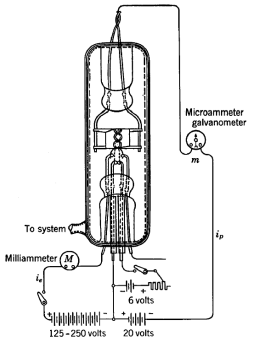
Radio Corporation
of America founded
1919

Irving Langmuir
Thoriated tungsten
filament
1920

Marconi/ de Forest/ Moorhead
reach agreement on patents
1919

Marconi IP501
1-Tube detector
1919

RCA Radiotron
UV-200, UV 201
1920



Saul Dushman and C. G. Found
Triode vacuum gauge
1921

Long distance telephone
repeaters put into use
in France
1920

XWA-AM
Montréal, Canada
Begins commercial
broadcasting
May 20, 1920

KDKA
Pittsburgh, Pennsylvania
Transmits first
licensed radio broadcast
November 2, 1920

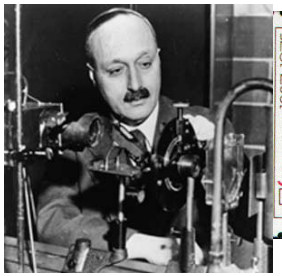
1922 – 1925

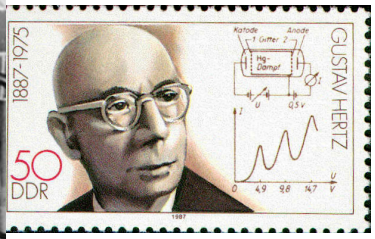
RCA Radiotron
WD-11
1922

Francis Aston
Nobel Prize in Chemistry
for discoveries made with his
mass spectrograph
1922

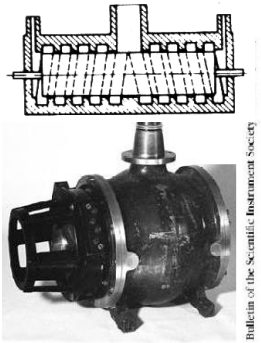
Robert A. Millikan
Nobel Prize in Physics
for measuring charge
on the electron
1923

Karl Manne Georg Siegbahn
(1886-1978) Nobel Prize in Physics
for x ray spectroscopy
1924





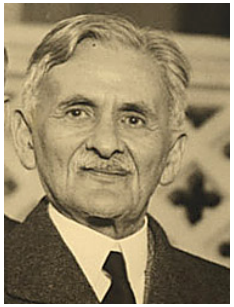
James Franck (1882-1964)
and Gustav Ludwig Hertz (1887-1975),
Nobel Prize in Physics for laws governing
collision between electron and atom
1925



Fernand Holweck (France)
(1890-1941)
Spiral drum molecular drag pump
1922

Irving Langmuir
Vibrating reed
(viscosity) vacuum gauge
1923

Lise Meitner
(1878-1968), Germany
Discovers the radiationless
electron transition (the
Auger effect, named for
Pierre Auger, France, who
re-discovered it in 1926)
1924



Albert Abraham Michelson
(1852-1931) with
Henry G. Gale and Fred Pearson
Interferometer measurements in
an evacuated tube agree with
Einstein's special and general
theories of relativity
1924-1925

de Forest Audion
tube enables sound-
on-film motion
picture cameras and
projectors
1922

First neon advertising
sign in U. S.
1923

Coolidge 4UD X ray tube
c. 1923

Wolfgang Gaede
Box Pump
Early 1920s

Allied Radio founded
1922

First Fleming
electron tube
patent expires
November 1922

Lee de Forest Co.
produces DV / DL
series vacuum tube
1923-1926

First de Forest
electron tube
patent expires
January 1924

L. T. Jones and H. G. Tasker
demonstrate electrostatic
focusing in a magnetically
deflected cathode ray tube
1924