Welcome to Quantum Mechanics 1

Welcome to Quantum Mechanics 2

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  Albert A. Michelson (1894)

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- "I cannot seriously believe in the quantum theory..."
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- "The more success the quantum theory has the sillier it looks."
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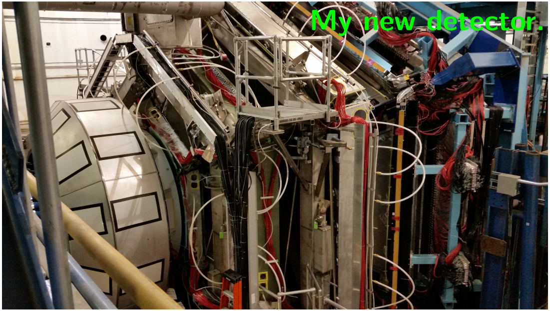
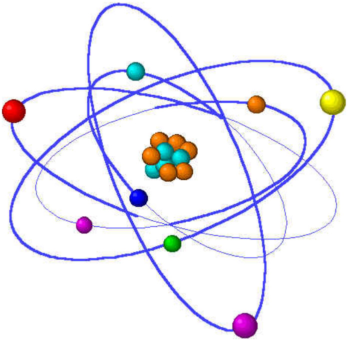
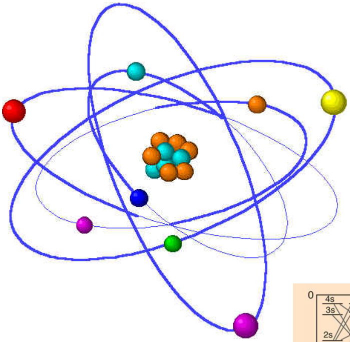
1. Start with a detector and take some data.
2. Develop the quantum program.
3. Apply the quantum program.
4. What are the classical alternatives?





← A toy atom.
Sim is here.

The Spectral Lines Problem



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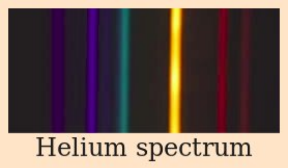
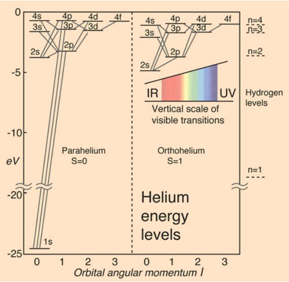
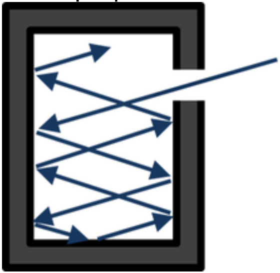
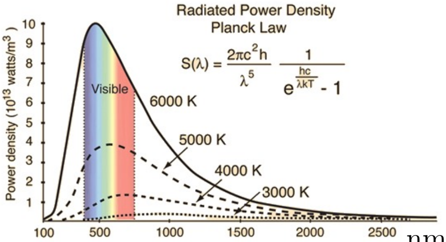




A black body is an idealized physical body that absorbs all incident electromagnetic radiation, regardless of frequency or angle of incidence. In thermal equilibrium (at a constant temperature) it emits electromagnetic radiation called black-body radiation with two notable properties.

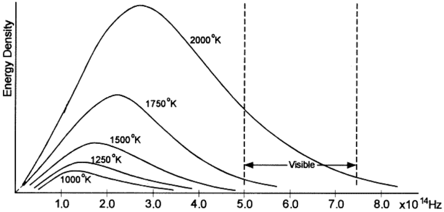
1. It is an ideal emitter: it emits as much or more energy at every frequency than any other body at the same temperature.
2. It is a diffuse emitter: the energy is radiated isotropically, independent of direction.





nm

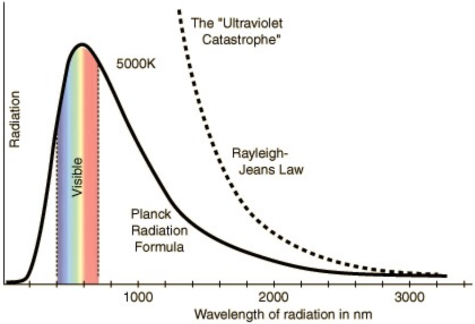
Wavelength (λ)

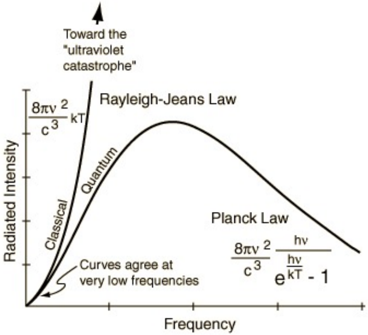


Frequency (ν)

Measured by Lummer and Pringsheim (1899).

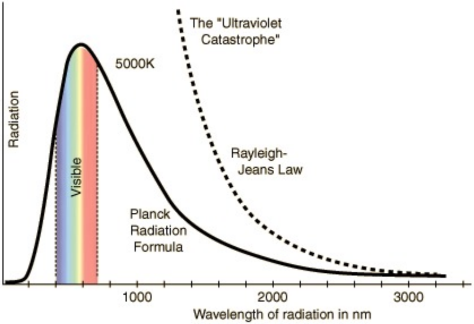
$$R_T(\nu)d\nu = \frac{\text{energy}}{\text{time-area}} \qquad \text{in the range } \nu \rightarrow \nu + d\nu$$

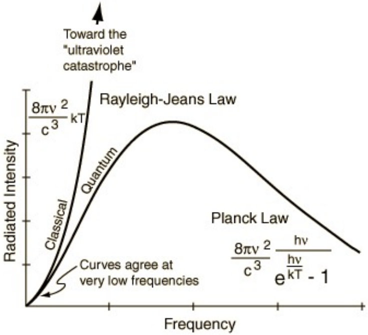




Rayleigh-Jeans Law

$$u(\nu)d\nu = \frac{8\pi}{c^3} k_B T \nu^2 d\nu \quad \text{in the range } \nu \rightarrow \nu + d\nu$$





$$\boxed{E = h\nu}$$

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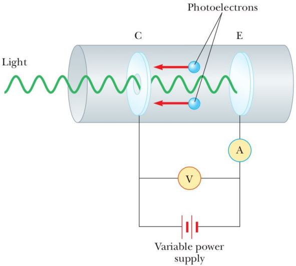
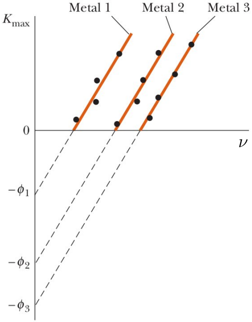
The Photoelectric Effect - Waves Acting Like Particles 12

1. Shine a light on metal and eject electrons.
2. Classical physics predicts that any frequency/wavelength of light will work as long as the light is intense enough.
3. Measurements by Lennard and others show very different behavior including a linear dependence on frequency and a lower limit. No intensity dependence.
4. Einstein uses Planck's hypothesis to explain it with a simple equation invoking the quantum hypothesis

$$K_{max} = eV_{stop} = E - \Phi = h\nu - \Phi$$

where Φ is the work function, V_{stop} is the minimum voltage for zero current, ν is the frequency of the light, and K_{max} is the maximum kinetic energy of the ejected electrons.

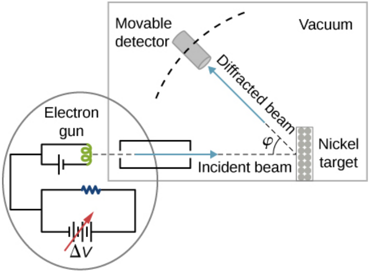


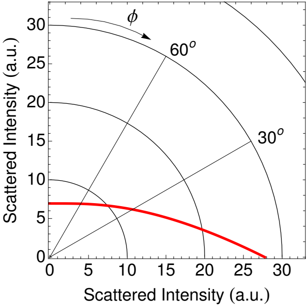


1. Shine a beam of electrons on crystalline nickel using the setup here.
2. In the polar plot at lower right the scattered electron intensity is proportional to the distance from the origin.
3. Classical physics predicts the electrons will collide with the nickel atoms and scatter to large angles. The intensity of scattered electrons should vary smoothly with angle (red curve).
4. The data (blue points) disagree wildly.
5. de Broglie solves it with electron waves

$$p = \frac{h}{\lambda}$$

where E is the kinetic energy.





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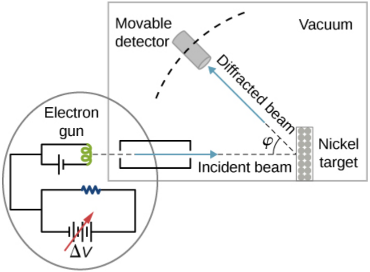
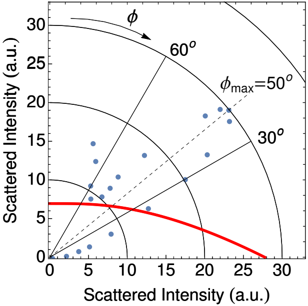


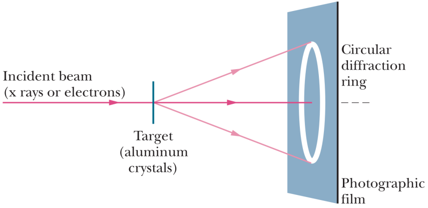


1. EM waves transmit energy and momentum.

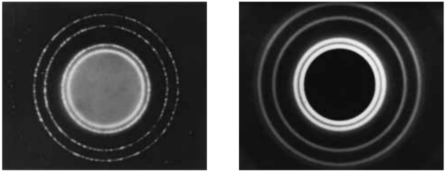
$$p = \frac{\text{energy absorbed}}{c} = \frac{E}{c}$$

2. de Broglie invokes symmetry to predict that particles will have wave properties.

$$p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$$



Apparatus to test de Broglie hypothesis.



Results for x-rays (left) and electrons (right).

1. In classical mechanics there is no limitation on the accuracy of our ability to measure the position $\vec{r}(t)$ and velocity $\vec{v}(t)$ of a particle.
2. The only limitations are experimental ones which can be overcome (hopefully) with improvements in technology and technique.
3. In wave mechanics (and quantum mechanics) this is no longer true!
4. For the motion of a quantum particle in one dimension the Heisenberg Uncertainty Principle is a fundamental limit that cannot be overcome. It is

$$\Delta x \Delta p_x \geq \frac{\hbar}{2}$$

where $\hbar = h/2\pi$, h is Planck's constant and the Δ's are the uncertainties.

- Spectral lines
- Blackbody radiation
- Photoelectric effect
- Specific heat freeze-out
- Compton effect
- Davisson-Germer
- Radioactivity
- Atomic structure/nuclear and particle physics

The current list:

https://en.wikipedia.org/wiki/List_of_unsolved_problems_in_physics