量子力学与统计物理

Quantum mechanics and statistical physics

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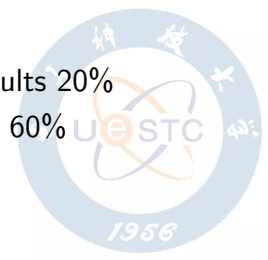
目录

课程目标

1. Learn the formal theory of Quantum Mechanics
2. How physical systems are described in Quantum Mechanics.
3. How to solve problems in Quantum Mechanics.

分数构成

1. Normal results 20%
2. Midterm examination results 20%
3. Final examination results 60%



参考书目

- 《量子力学》卷 I，II，曾谨言，科学出版社，2008
- Principles of quantum mechanics, shankar
- Modern quantum mechanics, shankar
- Lectures on quantum mechanics, weinberg
- Principles of quantum mechanics, Dirac

三条军规

1. Objects are wave-particles and can be in states of superposition
2. Rule 1 holds as long as you don't measure
3. Measurement gives random results

第一讲：普朗克能量子假说

经典物理伟大成就

1. Newtonian mechanics
2. Maxwell's electromagnetism
3. Thermodynamic laws

Great successes in Classical Physics

"There is nothing new to be discovered in physics now. All that remains is more and more precise measurements"

··· Lord Kelvin (1900)

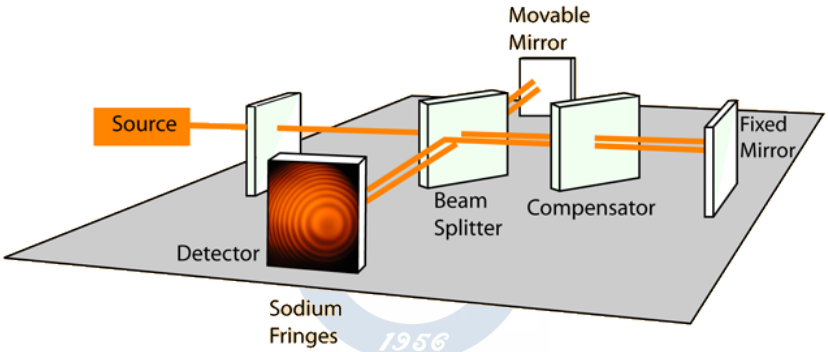
"But the beauty and clearness ... is obscured by two small puzzling clouds "

··· Lord Kelvin (1900.4)

1. Michelson-Morley experiment
2. Black body radiation

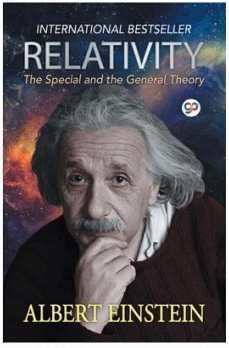
两朵乌云

迈克尔逊-莫雷实验



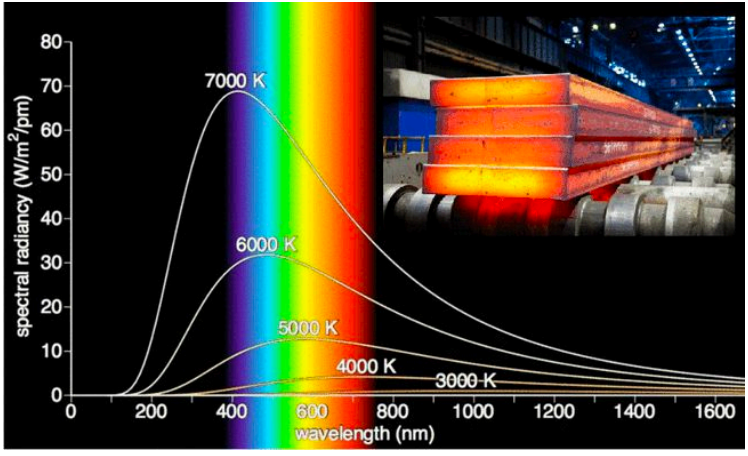
There is no displacement of the interference bands. ...the Stationary Ether is thus shown to be incorrect

The theory of relativity is established



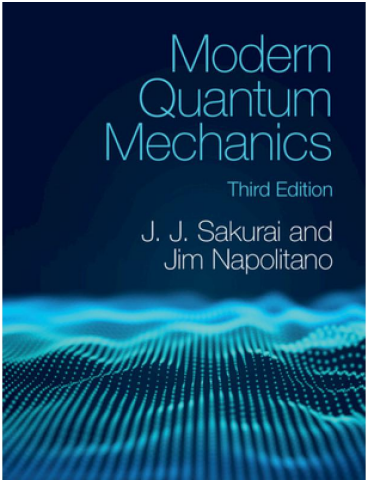
Greatly changed our view of time and space. Mainly useful in two aspects: high-speed motion, and strong gravitational field.

黑体辐射实验



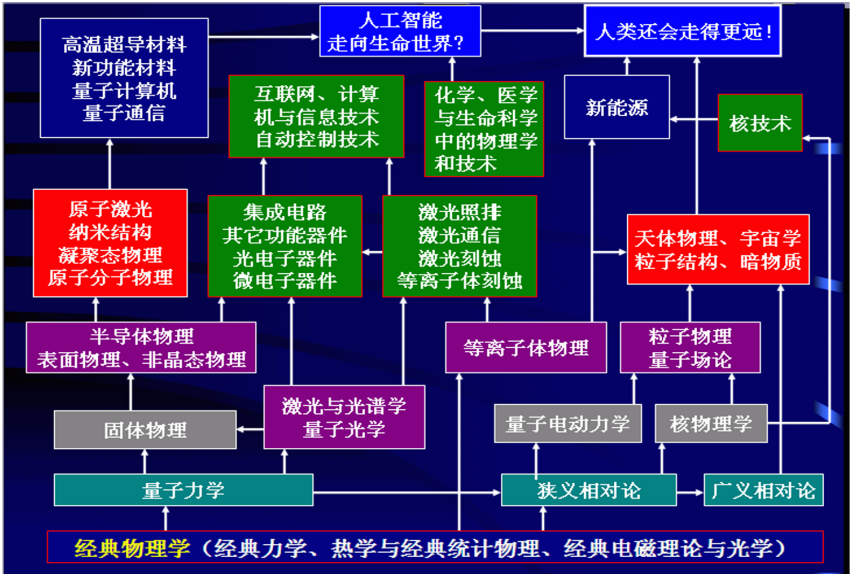
No mathematical function to describe the curves exactly

Quantum mechanics is established



It is a theory about matter.

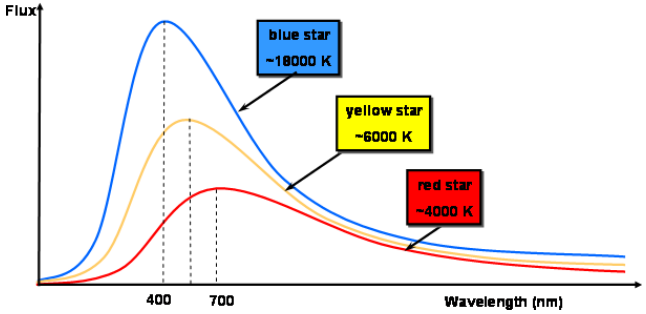
现代科学基石


高温超导材料
新功能材料
量子计算机
量子通信
人工智能
走向生命世界？
人类还会走得更远！
互联网、计算
机与信息技术
自动控制技术
化学、医学
与生命科学
中的物理学
和技术
新能源
核技术
原子激光
纳米结构
凝聚态物理
原子分子物理
集成电路
其它功能器件
光电子器件
微电子器件
激光照排
激光通信
激光刻蚀
等离子体刻蚀
天体物理、宇宙学
粒子结构、暗物质
半导体物理
表面物理、非晶态物理
等离子体物理
粒子物理
量子场论
固体物理
激光与光谱学
量子光学
量子电动力学
核物理学
量子力学
狭义相对论
广义相对论
经典物理学（经典力学、热学与经典统计物理、经典电磁理论与光学）

Black body radiation

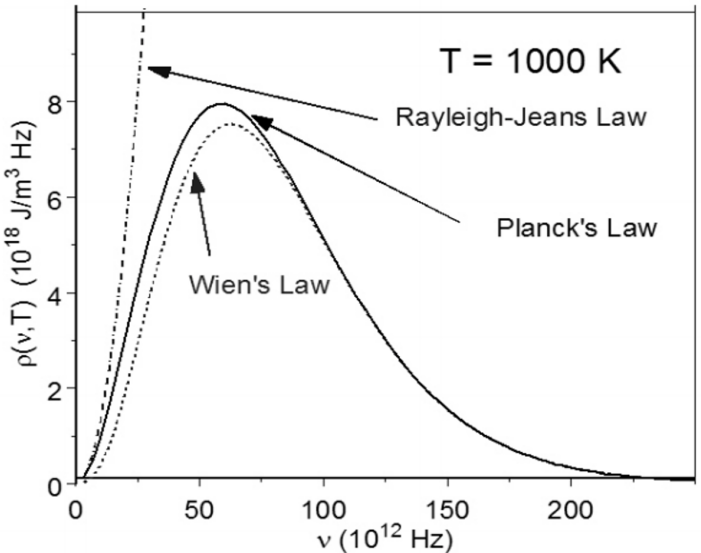
Definition of Black body

Absorb all electromagnetic waves in any temperature



Most interestingly, what is the mathematical function that describes all of these curves?

三个经验公式


T = 1000 K
Rayleigh-Jeans Law
Planck's Law
Wien's Law
ρ(ν,T) (10^18 J/m^3 Hz)
ν (10^12 Hz)
0
2
4
6
8
0
50
100
150
200

维恩公式

$$\rho(\nu)d\nu = c_1\nu^3 e^{-c_2\nu/T}d\nu$$

Derived from electromagnetism (1893), but described well only in high frequency region.

Nobel Prize in physics (1911)

瑞-金公式

$$\rho(\nu, T)d\nu = \frac{8\pi}{c^3}\nu^2 kT d\nu$$

Derived from thermodynamics (1900), but described well only in low frequency region.

Nobel Prize in physics (1904)

Ultraviolet Catastrophe:

$$\int_0^\infty \frac{8\pi}{c^3}\nu^2 kT \to \infty$$

普朗克公式

On 1900-10-19, at the German Physical Society, Max Planck presented a resolution to Ultraviolet Catastrophe

$$\rho(\nu, T)d\nu = \frac{8\pi}{c^3}\frac{h\nu^3}{e^{h\nu/KT} - 1}d\nu \tag{1}$$

Obtained from experimental data via interpolation technique (1900), described well in whole region

Nobel Prize in physics (1918)

Problem

How to derive the formula from existing theory.

Solution

On 1900-12-14, Planck gives out his solution based on the Energy Quantum Hypothesis

Energy quantum hypothesis

Assuming the oscillators of the cavity could only radiate at a discrete amounts of energy

$$E = n\varepsilon \tag{2}$$

where, the ε is the unit of the energy (quanta) determined by the oscillator' frequency

$$\varepsilon = h\nu \tag{3}$$

and the $h = 6.6260693(11) \times 10^{-34} J \cdot s$ is the Planck constant.

Based on Boltzmann distribution law,

$$\frac{N_i}{N} = \frac{\exp\left(-\frac{E_i}{kT}\right)}{\sum_i \exp\left(\frac{-E_i}{kT}\right)}$$

- when the energy is continuous， the distribution between $E - dE$ should be

$$\frac{e^{-E/kT}}{\int_0^\infty e^{-E/kT} dE}$$

the average energy

$$< E >= \int_0^\infty E \frac{e^{-E/kT}}{\int_0^\infty e^{-E/kT} dE} dE$$

$$< E > = -kT \frac{Ee^{-E/kT}|_0^\infty - \int_0^\infty e^{-E/kT} dE}{\int_0^\infty e^{-E/kT} dE}$$

$$= kT$$

- when the energy is discrete, the distribution should be

$$\frac{e^{-E/kT}}{\int_0^\infty e^{-E/kT} dE} \to \frac{e^{-E/kT}}{\sum_0^\infty e^{-E/kT}} \to \frac{e^{-nh\nu/kT}}{\sum_0^\infty e^{-nh\nu/kT}}$$

the average energy

$$< E > = \sum_0^\infty nh\nu \frac{e^{-nh\nu/kT}}{\sum_0^\infty e^{-nh\nu/kT}}$$

$$= -h\nu \frac{d}{dx} \frac{ne^{-nx}}{\sum_0^\infty e^{-nx}}$$

$$= \frac{h\nu}{e^{h\nu/kT} - 1}$$

We get

$$\text{(continuous)} \quad kT \to \frac{h\nu}{e^{h\nu/kT} - 1} \quad \text{(discrete)}$$

In Rayleigh-Jeans formula

$$\rho(\nu, T)d\nu = \frac{8\pi}{c^3}\nu^2 kT d\nu$$

the item kT should be replaced by $\frac{h\nu}{e^{h\nu/kT} - 1}$

$$\rho(\nu, T)d\nu = \frac{8\pi}{c^3}\frac{h\nu^3}{e^{h\nu/KT} - 1}d\nu$$

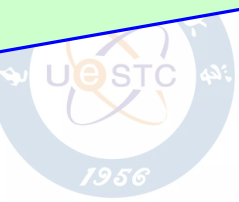
It is the Planck's formula exactly

Planck's Energy Quantum Hypothesis broke through the constraints of classical physics and opened the door of quantum mechanics

Revolutionary Significance

THE END

In 1927, Dirac got the Planck's formula from Quantum Mechanism.



学术讨论

能量量子化只是一种数学处理技术?

Thanks for your attention!

A & Q