§26

$M_\nu(T)$ $W/(m^2\cdot Hz)$ 能量（与温度有关）

$M(T)=\int_0^\infty M_\nu(T)\,d\nu$

…（平衡热辐射）

$a(\nu,T)$ 光谱吸收比 $=\frac{M_\nu(T)}{a(\nu)}$ 只与材料有关

黑体（绝对黑体）← 热辐射 $\left\{\begin{array}{l}\text{温度 } \checkmark \\ \text{材料性质 } \times\end{array}\right.$

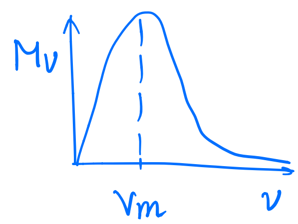
普朗克公式 $M_\nu=\frac{2\pi h}{c^2}\frac{\nu^3}{e^{h\nu/kT}-1}$ $E=nh\nu$ $(n=0,\cdots)$

黑体: $M(T)=\sigma T^4$ σ常量

维恩位移定律: $\nu_m=C_\nu T$ C_ν常量

↓

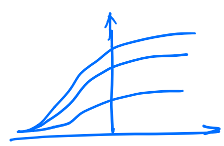
最大幅出光频率



光电效应

（饱和电流）

$i_m \propto I$（光强）



（截止电压）

$\frac{1}{2}mv_m^2=eU_c$ 光子最大初动能

↓

与光强无关

与频率有关 $U_c=K\nu-U_0$

常数

由金属决定

$\Rightarrow \frac{1}{2}mv_m^2=eK\nu-eU_0$

$\frac{1}{2}mv_m^2=eK(\nu-\nu_0)$ 红限频率（截止频率）

$\nu_0=\frac{U_0}{K}$

$\nu<\nu_0$ 时不发生光电效应

光量子论：~~E=hν (每个光子)~~

☆ $\frac{1}{2} m v_m^2 = h\nu - A$ A：逸出功 $\Rightarrow \nu_0 = \frac{U_0}{k} = \frac{A}{h}$ ☆

普朗克常量

$\frac{1}{2} m v_m^2 = ek\nu - eU_0$

U_c与ν有关

$E = mc^2 = \boxed{h\nu} \Rightarrow m = \frac{h\nu}{c^2} = \frac{h}{c\lambda}$

光子静止质量为0.

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

粒子	波动
$E =$	$h\nu$
$p =$	h/λ

eg. $\frac{1}{2} m v_m^2 = eU_c$

$A = h\nu - \frac{1}{2} m v_m^2 = h\frac{c}{\lambda} - eU_c$

$\nu_0 = A/h$

$A = h\frac{c}{\lambda} - eU_c$

$= h\frac{c}{\lambda_2} - eU_c'$

$\frac{1}{2} m v_c^2 = eU_c = e(k\nu - U_0)$

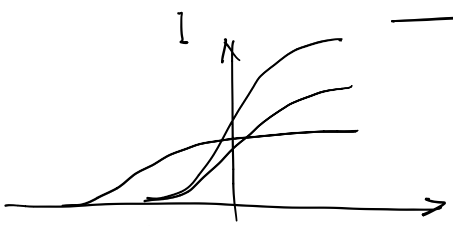
$= ek(\nu - \nu_0)$ $U_0 = k\nu_0$

$\nu_0 = \frac{A}{h} = \frac{U_0}{k}$ $\boxed{\nu = \frac{c}{\lambda}}$

$\frac{1}{2} m v_c^2 = h\nu - A$

$= eU_c$

$= hc/\lambda - A$



$\rightarrow i_m \propto I$

$\downarrow$

$U_c \propto \nu$

$\frac{1}{2} m v^2 = eU_c$

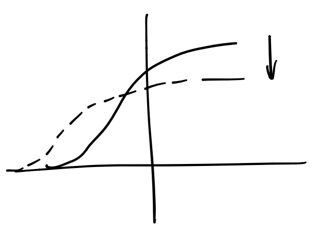
$= h\nu - A$

$A = eU_0 = \nu_0 h = \frac{c}{\lambda_0} h$

$\frac{ch}{eU_0}$

$\frac{c}{\lambda_0} = \nu_0$ $\cancel{\frac{1}{2} m v^2} = h\nu - A = h\nu - h\frac{c}{\lambda_0}$ ✓ $\nu_0 = \frac{U_0}{k} = \frac{A}{h}$

$= \sqrt{\left(h\frac{c}{\lambda_1} - h\frac{c}{\lambda_0}\right)\frac{2}{m_e}}$



$\downarrow$ I强，$\nu\uparrow$

$I = \frac{dN_光}{dt} \cdot h\nu \uparrow$

$\downarrow$

康普顿效应：有波长改变的散射

(X光才明显)

波长偏移与散射物质，入射波长无关

只与散射角有关 $\uparrow$ 正

$$\Delta\lambda = \lambda - \lambda_0 = \frac{h}{m_0 c}(1-\cos\varphi)$$

$$\lambda_c = \frac{h}{m_0 c}$$ (电子的康普顿波长)

$$\Rightarrow \quad \Delta\lambda = 2\lambda_c \sin\left(\frac{\varphi}{2}\right)^2$$

粒子波动性：实物粒子具有波粒二向性.（一切微观粒子）

光

$E = mc^2 = h\nu$

$p = h/\lambda$

$\Rightarrow$

一般实物粒子

$$\nu = \frac{E}{h} = \frac{mc^2}{h}$$

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

德布罗意波长

德布罗意公式

v 极大，电子的波长可以很小

散射极大条件. $d\sin\theta = \lambda$

eg. $p = h/\lambda \Rightarrow \lambda = \frac{h}{p} = \frac{h}{mv} \leftarrow \frac{1}{2}mv^2 = eU$

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

$$\boxed{Bqv = m\frac{v^2}{R}} \Rightarrow v = \sqrt{\frac{1}{m}BqvR}$$

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

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

$p = \frac{h}{\lambda}$ $\quad$ $\lambda = \frac{h}{mv}$ 一样.

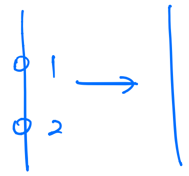
$$E_e = mc^2 = \frac{m_0 c^2}{\sqrt{1-v^2/c^2}}$$

$$p = mv = m_0 v \cdot \frac{1}{\sqrt{1-v^2/c^2}}$$

概率波.　波函数 $\Psi = \Psi(x,y,z,t) = \underline{\Psi(\vec{r},t)}$ → 概率幅.

$|\Psi|^2$ 概率密度

量子力学中：概率幅叠加而不是概率叠加



1,2孔打开后：$|\Psi_{12}|^2 = |\Psi_1 + \Psi_2|^2$

$\neq |\Psi_1|^2 + |\Psi_2|^2$

不确定关系：$\Delta x \cdot \Delta p_x \geq \frac{\hbar}{2}$　$\hbar = \frac{h}{2\pi}$ (常量) → x, y, z方向皆成立

* 在一个方向上，不确定 Δx 与不确定 Δp_x 有简单的关系

一个不确定量小了，另一个就会大

$$\Delta E \cdot \Delta t \geq \frac{\hbar}{2}$$

eg.

$$\boxed{E_{\sim} = \frac{hc}{\lambda} = h\frac{c}{1.2\lambda_0}}$$

$$E = E - E_{\sim} = h\frac{c}{\lambda_0} - \frac{1}{1.2}h\frac{c}{\lambda_0} = \frac{1}{6}h\frac{c}{\lambda_0}$$

$\frac{hc}{\lambda_0} - 0.1 = 0.4$　$\Delta = 0.1 = \frac{hc}{\Delta\lambda}$　$0.5 = \frac{hc}{\lambda_0}$　$\frac{0.1}{0.5} = 0.2$

$$E_k = \frac{hc}{\lambda_0} - \frac{hc}{\lambda} = \frac{\Delta\lambda}{\lambda_0} \cdot \frac{hc}{\lambda} = \frac{\Delta\lambda}{\lambda_0}(h\nu_0 - E_k)$$

$\Rightarrow \Delta\lambda = \frac{E_k}{(h\nu_0 - E_k)}$　　理解为能量守恒? √

$\lambda = \frac{h}{mv}$　相对论效应　$m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$

$\lambda = \frac{h}{mv}$ $v = \frac{h}{m\lambda}$ $\frac{1}{2}mv^2 = \frac{1}{2}m \cdot \frac{h^2}{m^2\lambda^2} = \frac{h^2}{2m\lambda^2}$

$E = \frac{hc}{\lambda} =$

薛定谔方程.

微观粒子运动状态 → $\Psi(x, y, z, t)$

微观粒子运动基本方程 → 薛定谔方程

$$\Psi(x,t) = \Psi_0 e^{-i(Et-px)/h}$$

(Ψ与Ψ_0一般是复数)

(一维自由粒子波函数)

$$\Psi(\vec{r},t) = \Psi_0 e^{-i(Et-\vec{p}\cdot\vec{r})/h}$$

(三维)

$$|\Psi(\vec{r},t)|^2 = \Psi(\vec{r},t) \cdot \Psi(\vec{r},t)^*$$

且 $\int |\Psi(\vec{r},t)|^2 dV = 1$

一维自由粒子含时薛定谔 $-\frac{\hbar^2}{2m} \cdot \frac{\partial^2 \Psi}{\partial x^2} = i\hbar \frac{\partial \Psi}{\partial t}$ (含有时间)

一维势场中运动粒子含时 $U(x,t)$

$$-\frac{\hbar^2}{2m} \frac{\partial^2 \Psi}{\partial x^2} + U(x,t)\Psi = i\hbar \frac{\partial \Psi}{\partial t}$$

三维即把 $\frac{\partial^2}{\partial x^2}$ 换成

($\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ 即可)

再记 $\hat{H} = \left(-\frac{\hbar^2}{2m}\nabla^2 + U(\vec{r},t)\right)$

$$\hat{H}\Psi = i\hbar \frac{\partial \Psi}{\partial t}$$

$$\boxed{-\frac{\hbar^2}{2m} \nabla^2 \Psi(\vec{r},t) + U(\vec{r},t)\Psi(\vec{r},t) = i\hbar \frac{\partial \Psi}{\partial t}}$$ ☆

解时间

本征波函数 ☆ 本征函数 ☆

(定态)

若 $U(\vec{r},t)$ 与 t 无关: $U(\vec{r})$. 则 $\Psi(\vec{r},t) = \Psi(\vec{r}) \cdot e^{-\frac{i}{\hbar}Et}$

$\Rightarrow |\Psi(\vec{r},t)|^2 = |\Psi(\vec{r})|^2$ ☆ (其实就是偏导换成导. 去掉时间)

概率分布不随时间变化

$$-\frac{\hbar^2}{2m} \cdot \frac{d^2\psi(x)}{dx^2} + U(x) \cdot \psi(x) = E\,\psi(x)$$ (一维定态)

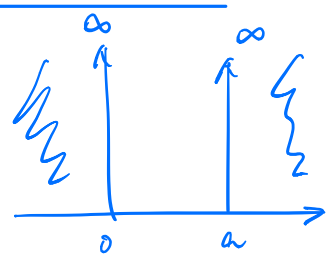
△波函数 ψ 服从叠加原理

3维下

$$-\frac{\hbar^2}{2m} \nabla^2 \psi(\vec{r}) + U(\vec{r})\psi(\vec{r}) = \psi(\vec{r})E$$

一维无限深方势阱

$$U(x) = \begin{cases} 0, & x \in [0,a] \\ \infty, & x \notin [0,a] \end{cases}$$



$\Rightarrow \psi(x) = 0$ (势阱外)

$\psi(x) = A\sin(kx+\varphi)$ (势阱内)

$= \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi}{a}x\right)$, $n = 1, \cdots$

$\Rightarrow E = E_n = \frac{\pi^2\hbar^2}{2ma^2} n^2$, $n = 1, 2, \cdots$

(能量量子化) → 基态能有

$\Rightarrow p_n = \pm\sqrt{2mE_n} = \pm k\hbar$

$\lambda_n = \frac{h}{p_n} = \frac{2a}{n}$ $n = 1, 2, \cdots$