$$\lambda' - \lambda = \frac{h}{m_o C}\{1 - \cos(\theta)\}$$

地球一周の距離 (外周)はおよそ4万Km

光の速度　$C = 2.99792458 \times 10^{10}$ cm/sec

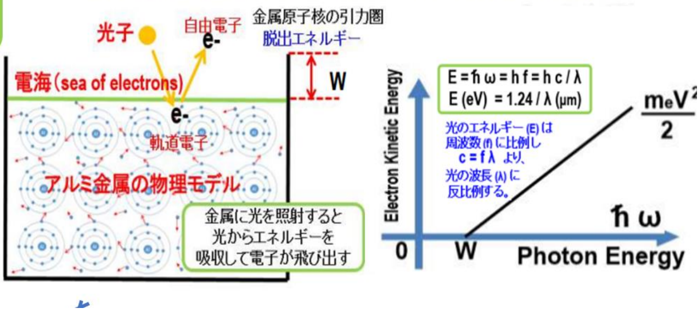
Plank 定数　$h = 6.62606957 \times 10^{-34}$ Joule･sec

電子の質量　$m_e = 9.10938291 \times 10^{-31}$ kg

Joule = Newton・m = (Kg・m・sec^{-2})・m

$$\frac{h}{m_o C} = 0.02426310241\,\text{Å}\ (10^{-8}\,\text{cm})$$

●金属の物理モデル(器の中に入った水モデル)



(2) $KE = \hbar\omega - \hbar\omega' = E - E_o = mc^2 - m_oc^2$

(3) $\omega t - Kx = K(ct - x)$　　(4) $\omega = cK = 2\pi c/\lambda$

(5) $c = f\lambda = (2\pi f)(\lambda/2\pi) = \omega/K$

(6) $E^2 - c^2P^2 = E_o^2$

(1) $E_o = m_oc^2$

For photon,

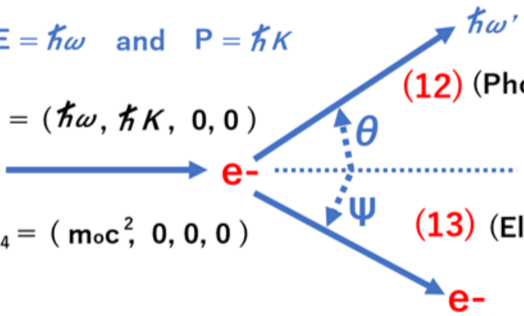
$E = \hbar\omega$ and $P = \hbar K$

$E^2 - c^2P^2 = 0$　$\omega = cK$

(7) $E^2 = (KE + m_oc^2)^2 = m_o^2c^4 + P^2c^2$　　(8) $P^2c^2 = (KE)^2 + 2m_oc^2(KE)$

(9) $P^2c^2 = (\hbar\omega - \hbar\omega')^2 + 2m_oc^2(\hbar\omega - \hbar\omega')$

For photon,　$E = \hbar\omega$　and　$P = \hbar K$



(10) $(\text{Photon})_4 = (\hbar\omega, \hbar K, 0, 0)$

(11) $(\text{Electron})_4 = (m_oc^2, 0, 0, 0)$

(12) $(\text{Photon})'_4 = (\hbar\omega', \hbar K'\cos(\theta), \hbar K'\sin(\theta), 0)$

(13) $(\text{Electron})'_4 = (mc^2, P\cos(\psi), -P\sin(\psi), 0)$

$(\text{Light})_4 = \hbar\cdot(\omega, K_x, K_y, K_z)$　　$(\text{Electron})_4 = (E, P_x, P_y, P_z)$　　$E^2 - c^2P^2 = E_o^2$

(2) $KE = \hbar\omega - \hbar\omega' = E - E_o = mc^2 - m_oc^2 = m_oc^2\left[\frac{1}{\sqrt{1 - v^2/c^2}} - 1\right] \sim \frac{m_ov^2}{2}$　for $v << c$

(14) $\hbar K = \hbar K'\cos(\theta) + P\cos(\psi)$

$\hbar K'\sin(\theta) = P\sin(\psi)$

(15) $P^2 = (\hbar K')^2 + (\hbar K)^2 - 2(\hbar K')(\hbar K)\cos(\theta)$

(9) $P^2c^2 = (\hbar\omega - \hbar\omega')^2 + 2m_oc^2(\hbar\omega - \hbar\omega')$

(16) $P^2 = (\hbar K - \hbar K')^2 + 2m_oC(\hbar K - \hbar K')$

(17) $-2(\hbar K')(\hbar K) + 2m_oC(\hbar K - \hbar K')$

$= -2(\hbar K')(\hbar K)\cos(\theta)$

(18) $m_oC(\hbar K - \hbar K')$

$= (\hbar K')(\hbar K)\{1 - \cos(\theta)\}$

(4) $\omega = cK = 2\pi c/\lambda$

$$\lambda' - \lambda = \frac{h}{m_oC}\{1 - \cos(\theta)\}$$