Chapter 6. The Solid Mass Photon and Atomic Spectra

1. The Solid Mass Photon

In chapter 1 it was proved from the 1^{st} postulate of special relativity that the speed of light is vector ally additive and consequently that Maxwell's Equations are false. In this chapter the first steps will be taken to provide the equations and dynamics to replace Maxwell's Equations and classical electrodynamics with equations and dynamics based on the solid mass atom and the solid mass photon.
Photons are hypothesized to be solid mass particles produced as collision products of two atoms (Discussed below), or as explosion products of an exploding atom (Chapter 3 section 10 and chapter 10, section 5).
As concerns photons produced by collision of atoms. Colliding solid mass atoms compress the atomic mass surface at the contact point resulting in percussive and shear waves that fan out between isopycnals from the contact point and re- converge at a point directly opposite the contact point releasing a solid mass particle here after called a photon. The physical details of this process are discussed in chapter 6, section 4.
Experimentally, atoms at very different temperatures can produce a given optical color, e.g. red. The surface of the sun at the accepted temperature of $6{,}000^{o}K$, a tungsten filament at $(800)(^{o}K)$ and an excited Geissler Tube at $350^{o}K$ all produce red light. This means that if the photons that produce red light are in thermal equilibrium with their parent atoms i.e. $T_{ph,R}=T_{At}$ where $\frac{1}{2}m_{ph,R}c^{2}_{ph,R}=\frac{3}{2}KT_{ph,R}$ and $\frac{1}{2}m_{At}V^{2}_{rms,At}=\frac{3}{2}KT_{At}$, then red light photons emitted at different T, have unequal kinetic energies. By hypothesis, all red light photons have the same momentum. See chapter 6, section 9.
The internal dynamics of an isolated photon are governed by equations of the form 3.15:

6.1 $\frac{1}{2}U^{2}(h_{ph})_{rms,ph}+\Psi(h_{ph})=C_{1,ph}$ where $h[r,t]_{ph}=r+\chi(r,t)_{ph}$,

$U_{ph}=\dot{h}_{ph}=\dot{\chi}(r,t)_{ph}$, where $\chi(r,0)_{ph}=0$, $h[r_{o_{ph}},t]_{ph}=r_{o_{ph}}+\chi(r_{o_{ph}},t)_{ph}$. h_{ph} and r are measured from a coordinate frame at rest w.r.t. the center of mass of the photon to any point within or on the surface of the photon. $r_{o_{ph}}$, represents the space averaged surface of the photon at t=0. Due to vibrational energy loss or gain by collision with atoms or with other photons, $C_{1,ph}$ is a function of t during collision and a constant between collisions.
Ignoring field forces acting on the photon, the total energy of the photon TE_{ph} is:
$TE_{ph}=\frac{1}{2}m_{ph}c^{2}_{ph}+m_{ph}C_{1,ph}$.

A given mass sample for large enough T, $T>0^{o}K$, is constantly emitting photons from the sample surface and is thus constantly losing energy to the external world. Assuming that the sample is not undergoing chemical or nuclear reactions, in order

to keep the sample at constant temperature T, a constant supply of energy must be supplied to the sample: $e_S = -e_{ex}$. Where e_S is the total photon and conductive thermal energy lost per second by the sample and provided to the external world at the sample surface and e_{ex} is the total energy per second provided by the external world to the sample at the sample surface. e_{ex} is provided by direct conductive thermal contact between the given mass and the external world and by photons emitted by the external world.

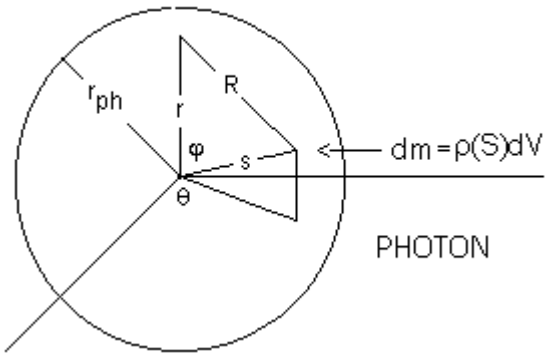
If the mass sample at temperature $T>0^oK$ is in empty outer space with no incoming photon energy, then the sample will spontaneously emit solid mass photons thereby losing energy continuously and the sample's temperature will approach $T \text{—>} 0^oK$ as $t \text{—>} \infty$. THERE IS NO GROUND STATE FOR THE SOLID MASS ATOM FOR $T>0^oK$.

Using 3.8, the field strength $\Psi(r)$ for the solid mass photon is written below.

6.2
$$\Psi_p(r) = -\frac{mH}{r_{ph}}\frac{(p+3)}{(p+2)}\left[1-\frac{1}{(p+3)}\left(\frac{r}{r_{ph}}\right)^{(p+2)}\right] \qquad p\neq -2\ ,\ r\leq r_{ph}$$
$$\Psi_{-2}(r) = -\frac{mH}{r_{ph}}\left[1+\ln\frac{r_{ph}}{r}\right] \qquad p=-2\ ,\ r\leq r_{ph}$$

where r is the distance from the center of the photon to any point within the photon.

FIGURE 6.1



2. $U^2_{rms}(r) = 2[C_1 - \Psi(r)] \geq 0$

Consider an isolated photon in vacuum for which. $U^2_{rms}(r) = 2[C_1 - \Psi_p(r)] \geq 0$

with $0 \leq r \leq r_{ph}$ where r_{ph} is the average photon radius·

From 3.28 for a photon with average photon radius r_{ph}: $C_1 \triangleq -\frac{mH}{r_{ph}}$

and using 6.2, $U^2_{rms}(r)=2[C_1-\Psi_p(r)]\doteq 2\frac{mH}{r_{ph}}\frac{1}{(p+2)}\left[1-(\frac{r}{r_{ph}})^{p+2}\right]$.

In order to compute $U^2_{rms}(r)$, it is assumed that $U^2_{rms}(r_{ph})<<2|\Psi_p(r_{ph})|$ see chapter 3, section 9.

$$U^2_{rms}(r)=2\frac{m_{ph}H}{r_{ph}}\frac{1}{(p+2)}\left[1-(\frac{r}{r_{ph}})^{p+2}\right]$$

$$U^2_{rms}(r)=-2\frac{m_{ph}H}{r_{ph}}\ln(\frac{r}{r_{ph}}),\ p=-2$$

$$U^2_{rms}(0)=\infty,\ -3<p\leq -2$$

$U_{rms}(0)$ has been computed for p=0 and is listed in table 6.3

3. Photon Binding Energy

From chapter 6, section 2 and the development of 3.29, the binding energy of the photon is given by:

6.3 $$BE_{ph}=m_{ph}C_1=-\frac{m^2_{ph}H}{r_{ph}}$$

$$r_{ph}\doteq -\frac{m^2_{ph}H}{BE_{ph}}$$

Table 6.1

n_1	n_2(ev)	m_{ph}(gm)
8	0.1	$(3.2)10^{-29}$
8	1.0	$(3.2)10^{-28}$
9	0.1	$(3.2)10^{-31}$
9	1.0	$(3.2)10^{-30}$
10	0.1	$(3.2)10^{-33}$
10	1.0	$(3.2)10^{-32}$
10.48	0.1	$(3.6)10^{-34}$
10.48	1.0	$(3.6)10^{-33}$
11	0.1	$(3.2)10^{-35}$
11	1.0	$(3.2)10^{-34}$

Table 6.1 lists m_{ph} as a function of speed $10^{n_1}\frac{cm}{sec}$ and kinetic energy n_2(ev). Solving $n_2(ev)=\frac{1}{2}m_{ph}c_{ph}^2(6.2\cdot10^{11})$ for m_{ph} yields: $m_{ph}=(3.2)10^{-2(6+n_1)}n_2$

Table 6.2 lists r_{ph} as a function of speed $10^{n_1}\frac{cm}{sec}$, kinetic energy n_2(ev) and binding energy be_{ph}(ev). Evaluating 6.3 for r_{ph} yields: $r_{ph}=-(6.4)10^{2(9-2n_1)}(\frac{n_2^2}{be_{ph}})$.

Table 6.2

n_1	n_2(ev)	be_{ph}(ev)	r_{ph}(cm)
8	0.1	-.10	$(6.4)10^{-15}$
8	0.1	-1.0	$(6.4)10^{-16}$
9	0.1	-.10	$(6.4)10^{-19}$
9	0.1	-1.0	$(6.4)10^{-20}$
10	0.1	-.10	$(6.4)10^{-23}$
10	0.1	-1.0	$(6.4)10^{-24}$
10.48	0.1	-0.1	$(7.7)10^{-25}$
10.48	0.2	-0.2	$(1.5)10^{-24}$
11	0.1	-.10	$(6.4)10^{-27}$
11	0.1	-1.0	$(6.4)10^{-28}$

Table 6.3 lists $\underset{rms}{U(0)}$ as a function of speed $10^{n_1}\frac{cm}{sec}$, kinetic energy n_2(ev), binding energy be_{ph}(ev) and p=0. Using $\underset{rms}{U^2(r)}=2\frac{mH}{r_{ph}}\frac{1}{(p+2)}\left[1-(\frac{r}{r_{ph}})^{p+2}\right]$ from chapter 6, section 2, $\underset{rms}{U^2(r)}$ becomes: $\underset{rms}{U(0)}=10^{n_1}(-\frac{be_{ph}}{(p+2)n_2})^{\frac{1}{2}}$, for $-2<p\leq 0$ and $\underset{rms}{U(0)}=\infty$, for $-3<p\leq-2$

Table 6.3

n_1	n_2(ev)	be_{ph}(ev)	p	$U(O)_{rms}\frac{cm}{sec}$
8	0.1	-.10	0	$(7.1)10^7$
8	0.1	-1.0	0	$(2.2)10^8$
9	0.1	-.10	0	$(7.1)10^8$
9	0.1	-1.0	0	$(2.2)10^9$
10	0.1	-.10	0	$(7.1)10^9$
10	0.1	-1.0	0	$(2.2)10^{10}$
10.48	0.1	-.10	0	$(2.1)10^{10}$
10.48	0.1	-1.0	0	$(6.7)10^{10}$
11	0.1	-.10	0	$(7.1)10^{10}$
11	0.1	-1.0	0	$(2.2)10^{11}$

4. Newton's 2nd Law Rewritten

Newton's Laws were originally written for mass points. Mass points do not exist and consequently Newton's Laws must be rewritten for liquids, solids and gases made up of continuous mass atoms each of which is separated by empty space. In general each atom in a liquid or a solid is coupled to two or more adjacent atoms while each atom in a gas maybe coupled to 0,1,2,...,6 atoms, the exact number depending on the coupled elements involved.
Let $\underset{\sim}{h}(\underset{\sim}{r}_1,t)$ represent the position of any point within or on the surface of a continuous mass atom at time t as measured from an inertial frame S. $\underset{\sim}{r}_1$ represents any point within or on the surface of the atom at t=0. $\underset{\sim}{h}(\underset{\sim}{r}_1,t)=[\underset{\sim}{r}_1+\underset{\sim}{\eta}(\underset{\sim}{r}_1,t)]$, $\underset{\sim}{h}(\underset{\sim}{r}_1,0)=\underset{\sim}{r}_1$, $\underset{\sim}{\eta}(\underset{\sim}{r}_1,0)=\underset{\sim}{0}$, $\dot{\underset{\sim}{h}}(\underset{\sim}{r}_1,t)=\dot{\underset{\sim}{\eta}}(\underset{\sim}{r}_1,t)$, $\ddot{\underset{\sim}{h}}(\underset{\sim}{r}_1,t)=\ddot{\underset{\sim}{\eta}}(\underset{\sim}{r}_1,t)$.

The position of the center of mass $\underset{\sim}{h}_{cm}$ of an atom of mass m_{At} is given by:

6.4 $$\underset{\sim}{h}(\underset{\sim}{r}_{cm},t)_{cm}=\frac{1}{m_{At}}\int_{V(t)}\rho(\underset{\sim}{h})\underset{\sim}{h}dV$$

Where V=V(t) is the volume of the atom as a function of time and S=S(t) is the bounding surface of V(t). $\underset{\sim}{h}_{cm}$, $\dot{\underset{\sim}{h}}_{cm}$ and $\ddot{\underset{\sim}{h}}_{cm}$ are also measured from inertial frame S. Let $\underset{\sim}{P}(\underset{\sim}{h})$ represent the pressure due to contact forces created by charge neutral

atoms and subatomic particles bouncing off of the atomic surface S(t) maintaining conservation of energy and momentum. Newton's second law becomes:

6.5(i) $$\int_{S(t)} \underset{\sim}{P}(\underset{\sim}{h})dA + \int_{V(t)} \rho(\underset{\sim}{h})\underset{\sim}{g}dV = \frac{d}{dt} m_{At} \dot{\underset{\sim}{h}}_{Cm} = \frac{d^2}{dt^2} \int_{V(t)} \rho(\underset{\sim}{h})\underset{\sim}{h}dV$$

Or using alternative notation:

6.5(ii) $$\underset{\sim}{F}(t)_{Tc} + \underset{\sim}{F}(t)_{Tf} = \frac{d}{dt} m_{At} \dot{\underset{\sim}{h}}_{Cm}$$

$\underset{\sim}{F}_{Tc}$ is the vector sum total of all external contact forces acting on S(t) where

$\underset{\sim}{F}_{Tc} \equiv \int_{S(t)} \underset{\sim}{P}(\underset{\sim}{h})dA$.

$\underset{\sim}{F}_{Tf}$ is the vector sum total of all externally caused field forces acting on the material in volume V(t) where $\underset{\sim}{F}_{Tf} \equiv \int_{V(t)} \rho(\underset{\sim}{h})\underset{\sim}{g}dV$ and where $\rho(\underset{\sim}{h})\underset{\sim}{g}$ is the force per unit volume due to externally caused field forces.

Classically given $\underset{\sim}{F}(t)_{Tc} + \underset{\sim}{F}(t)_{Tf}$, and $\underset{\sim}{h}(\underset{\sim}{r}_1,0)$ and $\dot{\underset{\sim}{h}}(\underset{\sim}{r}_1,0)$ for a mass point, one can solve 6.5(ii) for $\underset{\sim}{h}(\underset{\sim}{r}_1,t)$, $\dot{\underset{\sim}{h}}(\underset{\sim}{r}_1,t)$, $\ddot{\underset{\sim}{h}}(\underset{\sim}{r}_1,t)$. However 6.5(ii) is, strictly speaking, not correct.

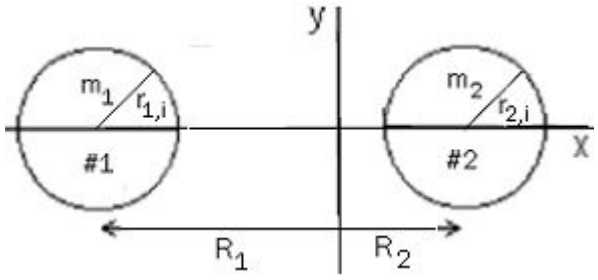
Consider; At time t_o atom #1 is struck by another atom in the radial direction. The collision increases the internal energy of atom #1 by $m_{At}\Delta C_1 = m_{At}C_{1,f} - m_{At}C_{1,i} > 0$ where $m_{At}C_{1,i} < 0$ represents the internal energy of the atom before collision and $m_{At}C_{1,f} < 0$ represents the internal energy of atom #1 after collision. A deformation force $\underset{\sim}{F}(t)_D$ produced by $\underset{\sim}{F}(t)_{Tc}$ will cause a change in the internal energy $m_{At}\Delta C_1$ where $\underset{\sim}{F}(t)_D = \int_{S(t)} \underset{\sim}{P}_D(\underset{\sim}{h})dA$ and $\underset{\sim}{P}_D$ is the deformation pressure acting on the surface of the atom. $\underset{\sim}{F}(t)_D$ goes into changing the density structure $\rho(\underset{\sim}{h})$, the mean radius and the internal and surface wave energy.

In order that 6.5(ii) hold rigorously, it is necessary that $|m_{At}\Delta C_1| << |\Delta KE_T|$ where KE_T is the translational kinetic energy of the atom. In the general case for which $m_{At}\Delta C_1$ cannot be ignored:

6.5(iii) $$\underset{\sim}{F}(t)_{Tc} - \underset{\sim}{F}(t)_D + \underset{\sim}{F}(t)_{Tf} = \frac{d}{dt} m_{At} \dot{\underset{\sim}{h}}_{Cm}$$

5. Newton's Laws Rewritten for Two Solid Mass Atoms Colliding Elastically

FIGURE A



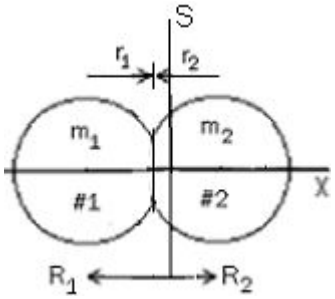
Central to the Newtonian concept of force, acceleration and velocity is the concept of the coordinate frame from which they are measured, i.e. the inertial frame. Consider two atoms on a center on center collision course, Fig A. At t=0 and before the two atoms collide, the center of mass of the 2 atoms is at the origin so that $m_1\underset{\sim}{R}_1(0)=-m_2\underset{\sim}{R}_2(0)$. If experimentally, $m_1\underset{\sim}{R}_1(t)=-m_2\underset{\sim}{R}_2(t)$, and assuming a mutual field force created by m_1 and m_2 is the only force acting on m_1 and m_2, then $\underset{\sim}{F}_{21}=m_1\ddot{\underset{\sim}{R}}_1(t)=-m_2\ddot{\underset{\sim}{R}}_2(t)=-\underset{\sim}{F}_{12}$: Newton's 3rd Law holds.
Now suppose that one is in a frame such that Newton's 3rd Law holds. Consequently, $m_1\ddot{\underset{\sim}{R}}_1(t)=-m_2\ddot{\underset{\sim}{R}}_2(t)$, $m_1\dot{\underset{\sim}{R}}_1(t)+m_2\dot{\underset{\sim}{R}}_2(t)=m_1\dot{\underset{\sim}{R}}_1(0)+m_2\dot{\underset{\sim}{R}}_2(0)=$const. and $m_1\underset{\sim}{R}_1(t)-m_1\underset{\sim}{R}_1(0)-m_1\dot{\underset{\sim}{R}}_1(0)t=-m_2\underset{\sim}{R}_2(t)+m_2\underset{\sim}{R}_2(0)+m_2\dot{\underset{\sim}{R}}_2(0)t$ consequently, $m_1\underset{\sim}{R}_1(t)=-m_2\underset{\sim}{R}_2(t)$ iff. $m_1\underset{\sim}{R}_1(0)=-m_2\underset{\sim}{R}_2(0)$ and $m_1\dot{\underset{\sim}{R}}_1(0)=-m_2\dot{\underset{\sim}{R}}_2(0)$.

Let m_{il} represent the mass of the inertial frame S. In order that S remain a non-accelerating inertial frame, it is required that $|\underset{\sim}{f}_{il,m_1}+\underset{\sim}{f}_{il,m_2}|<<|\underset{\sim}{f}(R_1)|=|-\underset{\sim}{f}(R_2)|$ where $\underset{\sim}{f}_{il,m_1}+\underset{\sim}{f}_{il,m_2}$ is the force on S due to m_1, plus the force on S due to m_2, and $\underset{\sim}{f}(R_1)$ is the force on m_1 due to m_2 and $\underset{\sim}{f}(R_2)$ is the force on m_2 due to m_1.

Atom #1 has mass m_1 and initial radius $r_{1,i}$ and atom #2 has mass m_2 and initial radius $r_{2,i}$ with $r_{1,i}\approx r_{2,i}$. The collision lasts Δt_c sec. where $\Delta t_c=t_{f,c}-t_{i,c}$. At $t_{i,c}$, the center to center distance S_i is $S_i=r_{1,i}+r_{2,i}=R_{1,i}+R_{2,i}$ and at $t_{f,c}$ the center to center distance is $S_f=r_{1,f}+r_{2,f}=R_{1,f}+R_{2,f}$ where due to deformation, S_f may not be equal to S_i. The force acting on atom #1 due to atom #2 during the collision is $\underset{\sim}{f}(S)_{21}$ and the force acting on atom #2 due to atom #1 during the collision is $\underset{\sim}{f}(S)_{12}$ where $S(t_{i,c})=S_i$ and $S(t_{f,c})=S_f$: $t_{i,c}\le t\le t_{f,c}$. $\underset{\sim}{f}(r_1,S)_{21}$ is the force on atom #1 due to atom #2 as if atom #1 were a point mass centered on the center of mass of atom #1 and $\underset{\sim}{f}(r_2,S)_{12}$ is the force on atom #2 due to atom #1 as if atom #2 were a point mass centered on the center of mass of atom #2. $\underset{\sim}{f}(r_1,S)_{21}$ is the sum of 2 forces, $\underset{\sim}{f}(r_1,S)_{21}=[\underset{\sim}{f}(S)_{21}]_{cb}+[\underset{\sim}{f}(r_1)_{21}]_c$

where $[\underset{\sim}{f}(r_1)_{21}]_c$ is the contact force on #1 due to #2 and $[\underset{\sim}{f}(S)_{21}]_{cb}$ is the chemical bond force on #1 due to #2. Similarly $\underset{\sim}{f}(r_2,S)_{12}=[\underset{\sim}{f}(r_2)_{12}]_c+[\underset{\sim}{f}(S)_{12}]_{cb}$. Using figure B, $S=R_1+R_2=r_1+r_2$, $\underset{\sim}{S}_{21}=\underset{\sim}{R}_1-\underset{\sim}{R}_2=\underset{\sim}{r}_2-\underset{\sim}{r}_1$, $\underset{\sim}{S}_{12}=\underset{\sim}{R}_2-\underset{\sim}{R}_1=\underset{\sim}{r}_1-\underset{\sim}{r}_2$.

FIGURE B



Using Figure A, the conservation of energy equations become:

6.5(iv) $[\Delta KE(S)_1]_{cb}=[\int_{R_{1,i}}^{R_1}\underset{\sim}{f}(S)_{21}d\underset{\sim}{R}_1]_{cb}=-[\Delta V_1]_{cb}$, and $[\Delta KE(S)_2]_{cb}=[\int_{R_{2,i}}^{R_2}\underset{\sim}{f}(S)_{12}d\underset{\sim}{R}_2]_{cb}=-[\Delta V_2]_{cb}$.

Assume you are in a frame such that BEFORE and AFTER the collision Newton's 3rd Law holds, $[\underset{\sim}{f}(S)_{21}]_{cb}=-[\underset{\sim}{f}(S)_{12}]_{cb}$ and therefore, $m_1\underset{\sim}{R}_1(t)=-m_2\underset{\sim}{R}_2(t)+m_1\underset{\sim}{R}_1(0)+m_2\underset{\sim}{R}_2(0)+\{m_1\dot{\underset{\sim}{R}}_1(0)+m_2\dot{\underset{\sim}{R}}_2(0)\}t$ and $[\underset{\sim}{f}(S)_{21}]_{cb}d\underset{\sim}{R}_1=-[\underset{\sim}{f}(S)_{12}]_{cb}d\underset{\sim}{R}_1=[\underset{\sim}{f}(S)_{12}]_{cb}\{\frac{m_2}{m_1}d\underset{\sim}{R}_2-[\dot{\underset{\sim}{R}}_1(0)+\frac{m_2}{m_1}\dot{\underset{\sim}{R}}_2(0)]dt\}$ and $[\underset{\sim}{f}(S)_{21}]_{cb}d\underset{\sim}{R}_1=[\underset{\sim}{f}(S)_{12}]_{cb}d\underset{\sim}{R}_2$ iff., $m_1=m_2$ and $[\dot{\underset{\sim}{R}}_1(0)+\frac{m_2}{m_1}\dot{\underset{\sim}{R}}_2(0)]=0$ and it is not at all clear that in general, $[\int_{R_{1,i}}^{R_1}\underset{\sim}{f}(S)_{21}d\underset{\sim}{R}_1]_{cb}=[\int_{R_{2,i}}^{R_2}\underset{\sim}{f}(S)_{12}d\underset{\sim}{R}_2]_{cb}$.

Given that $[\underset{\sim}{f}(S)_{21}]_{cb}=-[\underset{\sim}{f}(S)_{12}]_{cb}$ and $\underset{\sim}{S}_{21}=\underset{\sim}{R}_1-\underset{\sim}{R}_2$, $\underset{\sim}{S}_{12}=\underset{\sim}{R}_2-\underset{\sim}{R}_1$ and $m_1\neq m_2$ it will be proved that:

6.5(iv_a) $[\int_{R_{1,i}}^{R_1}\underset{\sim}{f}(S)_{21}d\underset{\sim}{R}_1]_{cb}=[\int_{R_{2,i}}^{R_2}\underset{\sim}{f}(S)_{12}d\underset{\sim}{R}_2]_{cb}$ iff. $[\underset{\sim}{f}(S)_{21}]_{cb}$ is an inverse square function.

If $m_1=m_2$ and $[\dot{\underset{\sim}{R}}_1(0)+\frac{m_2}{m_1}\dot{\underset{\sim}{R}}_2(0)]=0$ then 6.5(iv_a) holds for any integrable functions such that $[\underset{\sim}{f}(S)_{21}]_{cb}=-[\underset{\sim}{f}(S)_{12}]_{cb}$. With $S=R_1+R_2=r_1+r_2$ and $\underset{\sim}{S}_{21}=\underset{\sim}{R}_1-\underset{\sim}{R}_2$, $\underset{\sim}{S}_{12}=\underset{\sim}{R}_2-\underset{\sim}{R}_1$, and $d\underset{\sim}{R}_1=\{-\frac{m_2}{m_1}d\underset{\sim}{R}_2+[\dot{\underset{\sim}{R}}_1(0)+\frac{m_2}{m_1}\dot{\underset{\sim}{R}}_2(0)]dt\}$ by direct substitution:

$$[\int_{R_{1,i}}^{R_1} \underset{\sim}{f}(s)_{21}d\underset{\sim}{R}_1]_{cb}=\frac{m_2}{m_1+m_2}[\int_{\frac{m_2}{m_1+m_2}S_i}^{\frac{m_2}{m_1+m_2}S} \underset{\sim}{f}(s)_{21}d\underset{\sim}{S}_{21}]_{cb}+\frac{1}{m_1+m_2}[m_1\dot{\underset{\sim}{R}}_1(0)+m_2\dot{\underset{\sim}{R}}_2(0)][\int_0^t \underset{\sim}{f}(s(t))dt]_{21}^{cb} \text{ and}$$

$$[\int_{R_{2,i}}^{R_2} \underset{\sim}{f}(s)_{12}d\underset{\sim}{R}_2]_{cb}=\frac{m_1}{m_1+m_2}[\int_{\frac{m_1}{m_1+m_2}S_i}^{\frac{m_1}{m_1+m_2}S} \underset{\sim}{f}(s)_{21}d\underset{\sim}{S}_{21}]_{cb}+\frac{1}{m_1+m_2}[m_1\dot{\underset{\sim}{R}}_1(0)+m_2\dot{\underset{\sim}{R}}_2(0)][\int_0^t \underset{\sim}{f}(s(t))dt]_{21}^{cb}$$

Expand the integral in a power series: $\int \underset{\sim}{f}(s)_{21}d\underset{\sim}{S}_{21}=\sum_{n=-\infty}^{n=\infty}a_nS^n$. If $\int_{R_{1,i}}^{R_1} \underset{\sim}{f}(s)_{21}d\underset{\sim}{R}_1]_{cb}=[\int_{R_{2,i}}^{R_2} \underset{\sim}{f}(s)_{12}d\underset{\sim}{R}_2]_{cb}$ then term for term, $\frac{m_2}{m_1+m_2}a_n(\frac{m_2}{m_1+m_2})^n(S^n-S_i^n)=\frac{m_1}{m_1+m_2}a_n(\frac{m_1}{m_1+m_2})^n(S^n-S_i^n)$ and simplifying yields, $(m_2)^{n+1}=(m_1)^{n+1}$ with solutions n=-1 and/or $m_2=m_1$.
It has been proved that given $[\underset{\sim}{f}(S)_{21}]_{cb}=-[\underset{\sim}{f}(S)_{12}]_{cb}$ and $\underset{\sim}{S}_{21}=\underset{\sim}{R}_1-\underset{\sim}{R}_2$, $\underset{\sim}{S}_{12}=\underset{\sim}{R}_2-\underset{\sim}{R}_1$ and $m_1\neq m_2$, that $\int_{R_{1,i}}^{R_1} \underset{\sim}{f}(s)_{21}d\underset{\sim}{R}_1]_{cb}=[\int_{R_{2,i}}^{R_2} \underset{\sim}{f}(s)_{12}d\underset{\sim}{R}_2]_{cb}$ iff. $[\underset{\sim}{f}(S)_{21}]_{cb}$ is an inverse square function.

If $m_1=m_2$ and $[\dot{\underset{\sim}{R}}_1(0)+\frac{m_2}{m_1}\dot{\underset{\sim}{R}}_2(0)]=0$ then $\int_{R_{1,i}}^{R_1} \underset{\sim}{f}(s)_{21}d\underset{\sim}{R}_1]_{cb}=[\int_{R_{2,i}}^{R_2} \underset{\sim}{f}(s)_{12}d\underset{\sim}{R}_2]_{cb}$ holds for any integrable functions for which $[\underset{\sim}{f}(S)_{21}]_{cb}=-[\underset{\sim}{f}(S)_{12}]_{cb}$. Equating results:

6.5(v) $$[\Delta KE(S)_1]_{cb}=[\int_{R_{1,i}}^{R_1} \underset{\sim}{f}(s)_{21}d\underset{\sim}{R}_1]_{cb}=-[\Delta V_1]_{cb}=[\Delta KE(S)_2]_{cb}=[\int_{R_{2,i}}^{R_2} \underset{\sim}{f}(s)_{12}d\underset{\sim}{R}_2]_{cb}=-[\Delta V_2]_{cb}$$

iff. $[\underset{\sim}{f}(S)_{21}]_{cb}=-[\underset{\sim}{f}(S)_{12}]_{cb}$ and $[\underset{\sim}{f}(S)_{21}]_{cb}$ and $[\underset{\sim}{f}(S)_{12}]_{cb}$ are inverse square functions,

From which it immediately follows that the change in total energy=0

6.5(vi) $$[\Delta KE(S)_1]_{cb}+[\Delta KE(S)_2]_{cb}+[\Delta V_1]_{cb}+[\Delta V_2]_{cb}=0$$
$$[\Delta KE(S)_1]_{cb}=[\Delta KE(S)_2]_{cb}=-[\Delta V_1]_{cb}=-[\Delta V_2]_{cb}$$

Although the above analysis is for 2 atoms attracted by a field force before and after collision, the analysis holds for any 2 macroscopic objects attracted by a field force.

Note that although $[\int_{S_i}^{S} \underset{\sim}{f}(S)_{21} d\underset{\sim}{S}_{21}]_{cb} = [\int_{S_i}^{S} \underset{\sim}{f}(S)_{12} d\underset{\sim}{S}_{12}]_{cb}$ for any integrable function $[\underset{\sim}{f}(S)_{21}]_{cb}$

subject to $[\underset{\sim}{f}(S)_{21}]_{cb} = -[\underset{\sim}{f}(S)_{12}]_{cb}$ and $d\underset{\sim}{S}_{21} = -d\underset{\sim}{S}_{12}$: $[\int_{S_i}^{S} \underset{\sim}{f}(S)_{21} d\underset{\sim}{S}_{21}]_{cb} \neq [\Delta KE(S)_1]_{cb}$ as

$$[\Delta KE(S)_1]_{cb} = [\int_{R_{1,i}}^{R_1} \underset{\sim}{f}(S)_{21} d\underset{\sim}{R}_1]_{cb} = \frac{m_1}{m_1+m_2}[\int_{\frac{m_1}{m_1+m_2}S_i}^{\frac{m_1}{m_1+m_2}S} \underset{\sim}{f}(S)_{21} d\underset{\sim}{S}_{21}]_{cb} + \frac{1}{m_1+m_2}[m_1\dot{\underset{\sim}{R}}_1(0) + m_2\dot{\underset{\sim}{R}}_2(0)][\int_0^t \underset{\sim}{f}(s(t))_{21} dt]_{cb} \neq [\int_{S_i}^{S} \underset{\sim}{f}(S)_{21} d\underset{\sim}{S}_{21}]_{cb}$$

A similar argument holds to show that $[\int_{S_i}^{S} \underset{\sim}{f}(S)_{12} d\underset{\sim}{S}_{12}]_{cb} \neq \Delta KE(S)_{2,cb}$.

If $[\underset{\sim}{f}(S)_{21}]_{cb} = -[\underset{\sim}{f}(S)_{12}]_{cb}$ but $[\underset{\sim}{f}(S)_{21}]_{cb}$ and $[\underset{\sim}{f}(S)_{12}]_{cb}$ are not inverse square functions, then 6.5(iv) still holds but $[\int_{R_{1,i}}^{R_1} \underset{\sim}{f}(S)_{21} d\underset{\sim}{R}_1]_{cb} \neq [\int_{R_{2,i}}^{R_2} \underset{\sim}{f}(S)_{12} d\underset{\sim}{R}_2]_{cb}$ and therefore $[\underset{\sim}{f}(S)_{21}]_{cb}$ and $[\underset{\sim}{f}(S)_{12}]_{cb}$ do not represent physical, experimental reality.

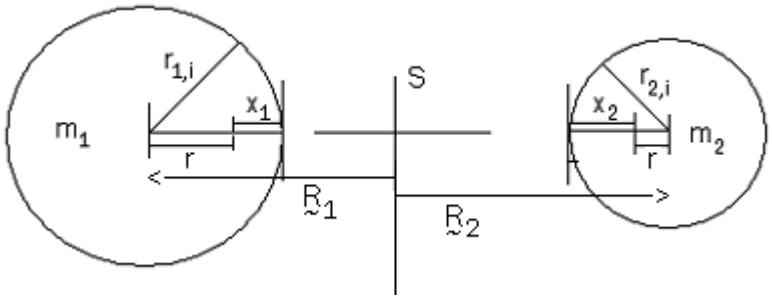
Turning now to the atoms at collision; from appendix 10A, the total internal energy of the atoms is:

$$[T_1]_c + [V_1]_c = \tfrac{1}{2} m_1 U_{rms}^2(r_1) - \frac{m_1^2 H}{r_1} < 0 \quad \text{for } -3 < p_1 \leq 0$$

$$[T_2]_c + [V_2]_c = \tfrac{1}{2} m_2 U_{rms}^2(r_2) - \frac{m_2^2 H}{r_2} < 0 \quad \text{for } -3 < p_2 \leq 0$$

Ignoring the cb force for the moment, and using Figure C below, define $x_1 = r_{1,i} - r$ and $x_2 = r_{2,i} - r$. All measurements are made from inertial frame S.

FIGURE C



The conservation of energy equations for the 2 atoms in collision c during time t, $t_{i,c} \leq t \leq t_{f,c}$ are:

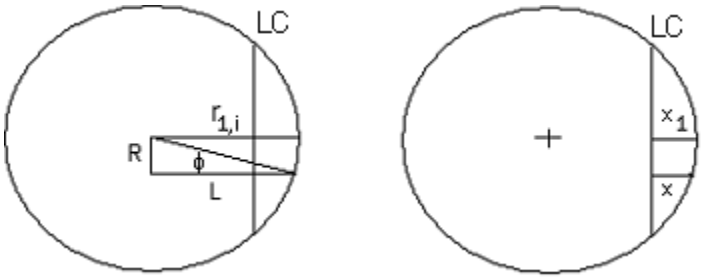
6.5(vii) $\Delta KE(r_1)_{1,c}+\Delta T_{1,c}=[\int_{R_{1,i}}^{R_1}(\underset{\sim}{f}(x_1)_{21}d\underset{\sim}{R}_1]_c=-\Delta V_{1,c}$ and $\Delta KE(r_2)_{2,c}+\Delta T_{2,c}=[\int_{R_{2,i}}^{R_2}(\underset{\sim}{f}(x_2)_{12}d\underset{\sim}{R}_2]_c=-\Delta V_{2,c}$

Using 3.4, 3.8 and 3.19 derive the pressure $P_1(x_1)$ at x_1 in the interior of isolated m_1, yielding: $P_1(x_1)=\frac{m_1^2H(p_1+3)}{24\pi r_{1,i}^4(p_1+1)}[1-(\frac{r_1}{r_{1,i}})^{2(p_1+1)}]=\frac{m_1^2H(p_1+3)}{24\pi r_{1,i}^4(p_1+1)}[1-(1-\frac{x_1}{r_{1,i}})^{2(p_1+1)}]\doteq\frac{m_1^2H(p_1+3)}{12\pi r_{1,i}^4}(\frac{x_1}{r_{1,i}})$

Similarly, in the interior of isolated m_2, $P_2(x_2)=\frac{m_2^2H(p_2+3)}{12\pi r_{2,i}^4}(\frac{x_2}{r_{2,i}})$.

Using Figure D, $L=r_{1,i}\cos\phi$, $R=r_{1,i}\sin\phi$, $x=x_1-(r_{1,i}-L)=x_1-r_{1,i}(1-\cos\phi)$, $\phi=\cos^{-1}(1-\frac{x_1-x}{r_{1,i}})$.

FIGURE D



With $\phi_o\equiv\cos^{-1}(1-\frac{x_1}{r_{1,i}})$, the collision force $[f(x_1)_{21}]_c$ acting on m_1 due to collision with m_2 during time $t_{i,c}\le t\le t_{i,f}$, is:

$[f(x_1)_{21}]_c=\int_{A_1}^{A_2}P_1(x)dA=2\pi\int_0^{R_0}RP_1(x)dR=\frac{m_1^2H(p_1+3)}{6r_{1,i}^2}\int_0^{\phi_0}(\frac{x_1}{r_{1,i}}-1+\cos\phi)\sin\phi\cos\phi\,d\phi$. Integrating $[f(x_1)_{21}]_c$ yields: $[f(x_1)_{21}]_c=\frac{m_1^2H(p_1+3)}{6r_{1,i}^2}[\frac{1}{2}(\frac{x_1}{r_{1,i}}-1)\sin^2\phi-\cos\phi+\frac{1}{3}\cos\phi(\sin^2\phi+2)]\Big|_0^{\phi_0}=\frac{m_1^2H(p_1+3)}{12r_{1,i}^2}(\frac{x_1}{r_{1,i}})^2(1-\frac{1}{3}\frac{x_1}{r_{1,i}})\doteq B_1(\frac{x_1}{r_{1,i}})^2$ where $B_1\equiv\frac{m_1^2H(p_1+3)}{12r_{1,i}^2}$. In vector form, $[\underset{\sim}{f}(x_1)_{21}]_c=-\frac{m_1^2H(p_1+3)}{12r_{1,i}^2}(\frac{x_1}{r_{1,i}})^2\hat{x}$.

Similarly, $[f(x_2)_{12}]_c=\frac{m_2^2H(p_2+3)}{12r_{2,i}^2}(\frac{x_2}{r_{2,i}})^2=B_2x_2^2$ where $B_2\equiv\frac{m_2^2H(p_2+3)}{12r_{2,i}^2}$. In vector form, $[\underset{\sim}{f}(x_2)_{12}]_c=\frac{m_2^2H(p_2+3)}{12r_{2,i}^2}(\frac{x_2}{r_{2,i}})^2\hat{x}$. The force is created at the collision surface, Fig. B along the line of collision LC, Figure D.

Assuming Newton's 3rd Law $[\underset{\sim}{f}(x_1)_{21}]_c=-[\underset{\sim}{f}(x_2)_{12}]_c$ find:

6.5(vii$_a$) $\underset{\sim}{x}_1=-[\frac{(p_2+3)}{(p_1+3)}]^{\frac{1}{2}}(\frac{r_{1,i}}{r_{2,i}})^2\frac{m_2}{m_1}\underset{\sim}{x}_2\neq -\frac{m_2}{m_1}\underset{\sim}{x}_2$

for non-identical atoms. Using fig. B, $[\underset{\sim}{f}(x_1)_{21}]_c=m_1\ddot{\underset{\sim}{R}}_1=-[\underset{\sim}{f}(x_2)_{12}]_c=-m_2\ddot{\underset{\sim}{R}}_2$ as measured from inertial frame S. If $[\underset{\sim}{f}(x_1)_{21}]_c=m_1\ddot{\underset{\sim}{x}}_1$ then from symmetry considerations $[\underset{\sim}{f}(x_2)_{12}]_c=m_2\ddot{\underset{\sim}{x}}_2$ and therefore $[\underset{\sim}{f}(x_1)_{21}]_c=m_1\ddot{\underset{\sim}{x}}_1=-[\underset{\sim}{f}(x_2)_{12}]_c=-m_2\ddot{\underset{\sim}{x}}_2$ but $m_1\ddot{\underset{\sim}{x}}_1=-[\frac{(p_2+3)}{(p_1+3)}]^{\frac{1}{2}}(\frac{r_{1,i}}{r_{2,i}})^2m_2\ddot{\underset{\sim}{x}}_2\neq -m_2\ddot{\underset{\sim}{x}}_2$, consequently $[\underset{\sim}{f}(x_1)_{21}]_c\neq m_1\ddot{\underset{\sim}{x}}_1$ and from symmetry considerations, $[\underset{\sim}{f}(x_2)_{12}]_c\neq m_2\ddot{\underset{\sim}{x}}_2$

With $[\underset{\sim}{f}(x_1)_{21}]_c=-B_1x_1^2\hat{x}=-B_2x_2^2\hat{x}$ and $[\underset{\sim}{f}(x_2)_{12}]_c=B_2x_2^2\hat{x}=B_1x_1^2\hat{x}$ find:

$[\int_{R_{1,i}}^{R_1}\underset{\sim}{f}(R_1)_{21}\,d\underset{\sim}{R}_1]_c=[\int_0^{x_1}\underset{\sim}{f}(x_1)_{21}\,d\underset{\sim}{x}_1]_c=[\int_0^{x_1}B_1x_1^2dx_1]_c=\frac{1}{3}B_1x_1^3$ similarly,

$[\int_{R_{2,i}}^{R_2}\underset{\sim}{f}(R_2)_{12}\,d\underset{\sim}{R}_2]_c=[\int_0^{x_2}\underset{\sim}{f}(x_2)_{12}\,d\underset{\sim}{x}_2]_c=[\int_0^{x_2}B_2x_2^2dx_2]_c=\frac{1}{3}B_2x_2^3$. Setting $\frac{1}{3}B_1x_1^3=\frac{1}{3}B_2x_2^3$ find

$x_1=(\frac{(p_2+3)}{(p_1+3)})^{\frac{1}{3}}(\frac{r_{1,i}}{r_{2,i}})^{\frac{4}{3}}(\frac{m_2}{m_1})^{\frac{2}{3}}x_2$ which is inconsistent with 6.5(vii$_a$). Therefore if $[\underset{\sim}{f}(x_1)_{21}]_c=-[\underset{\sim}{f}(x_2)_{12}]_c$ then $[\int_{R_{1,i}}^{R_1}\underset{\sim}{f}(R_1)_{21}\,d\underset{\sim}{R}_1]_c\neq[\int_{R_{2,i}}^{R_2}\underset{\sim}{f}(R_2)_{12}\,d\underset{\sim}{R}_2]_c$. This solution is non-physical as it means there is no connection between the kinetic energy and potential energy of m_1 and the kinetic energy and potential energy of m_2. If however, $[\int_{R_{1,i}}^{R_1}\underset{\sim}{f}(R_1)_{21}\,d\underset{\sim}{R}_1]_c=[\int_{R_{2,i}}^{R_2}\underset{\sim}{f}(R_2)_{12}\,d\underset{\sim}{R}_2]_c$ then, 6.5(vii$_a$) is false and $[\underset{\sim}{f}(x_1)_{21}]_c\neq-[\underset{\sim}{f}(x_2)_{12}]_c$ i.e. Newton's 3rd law is false and with $R_1=R(t)_1$, $R_2=R(t)_2$: Considering $\underset{\sim}{f}_{21}$ and $\underset{\sim}{f}_{12}$ to be made of two linearly independent functions $\underset{\sim}{f}_{TKE}$ and $\underset{\sim}{f}_{IKE}$ where TKE stands for Translational Kinetic Energy and IKE stands for Internal Kinetic Energy, find:

$\Delta KE(t)_{1,c}=[\int_{R_{1,i}}^{R_1}\underset{\sim}{f}(R_1)_{21,TKE}\,d\underset{\sim}{R}_1]_c=\Delta KE(t)_{2,c}=[\int_{R_{2,i}}^{R_2}\underset{\sim}{f}(R_2)_{12,TKE}\,d\underset{\sim}{R}_2]_c$ and

$\Delta T(t)_{1,c}=[\int_{R_{1,i}}^{R_1}\underset{\sim}{f}(R_1)_{21,IKE}\,d\underset{\sim}{R}_1]_c=-\Delta V(t)_{1,c}=\Delta T(t)_{2,c}=[\int_{R_{2,i}}^{R_2}\underset{\sim}{f}(R_2)_{12,IKE}\,d\underset{\sim}{R}_2]_c=-\Delta V(t)_{2,c}$

6.5(viii$_a$) $\Delta KE(t)_{1,c}=\Delta KE(t)_{2,c}$

6.5(viii$_b$) $\Delta T(t)_{1,c}=-\Delta V(t)_{1,c}=\Delta T(t)_{2,c}=-\Delta V(t)_{2,c}$

The total change in energy=0. If photons are created, then the energy to create the photon must be taken into consideration.

If one assumes that the atoms are perfect spheres during collision, then due to symmetry considerations, the internal momentum of each atom sums to zero. The conservation of momentum equations $\int_{t_{i,c}}^{t} \underset{\sim}{f}(x_1)_{21}dt=\Delta m_1\underset{\sim}{v}(t)_1=-\int_{t_{i,c}}^{t}\underset{\sim}{f}(x_2)_{12}dt=\Delta m_2\underset{\sim}{v}(t)_2$ yield: $m_1\underset{\sim}{v}(t)_1+ m_2\underset{\sim}{v}(t)_2=m_1\underset{\sim}{v}(t_{i,c})_1+ m_2\underset{\sim}{v}(t_{i,c})_2$ and differentiating yields $[\underset{\sim}{f}(t)_{21}]_c=-[\underset{\sim}{f}(t)_{12}]_c$ which is false. Consequently the conservation of momentum equations become:

6.5(ix) $m_1\underset{\sim}{v}(t)_1+\underset{\sim}{\Phi}(t)_1+m_2\underset{\sim}{v}(t)_2+\underset{\sim}{\Phi}(t)_2=m_1\underset{\sim}{v}(t_{i,c})_1+\underset{\sim}{\Phi}(t)_{1,i}+ m_2\underset{\sim}{v}(t_{i,c})_2+\underset{\sim}{\Phi}(t)_{2,i}$=const.

Where the $\underset{\sim}{\Phi}$'s represent the internal momentum due to collision caused atom asymmetry and where $\underset{\sim}{v}(t)_1=\dot{\underset{\sim}{R}}_1$, $\underset{\sim}{v}(t)_2=\dot{\underset{\sim}{R}}_2$ and $[T_1]_c+[V_1]_c=\frac{1}{2}m_1U^2_{rms}(r_1)-\frac{m_1^2H}{r_1}<0$, $[T_2]_c+[V_2]_c=\frac{1}{2}m_2U^2_{rms}(r_2)-\frac{m_2^2H}{r_2}<0$. Rewrite 6.5(viii$_a$) and 6.5(ix) in linear form.

6.5(x$_a$) $\frac{1}{2}m_1V_1^2(t)-\frac{1}{2}m_2V_2^2(t)=\frac{1}{2}m_1V_1^2(t_{i,c})-\frac{1}{2}m_2V_2^2(t_{i,c})=K_1$=const., $t_{i,c}\le t\le t_{f,c}$

$m_1V_1(t)-\Phi_1(t)-m_2V_2(t)+\Phi_2(t)=m_1V_1(t_{i,c})-\Phi_1(t_{i,c})-m_2V_2(t_{i,c})+\Phi_2(t_{i,c})=K_2$=const.

It is left as a problem to solve 6.5(x$_a$) in terms of the functions $\Phi_1(t)$ and $\Phi_2(t)$ and the constants, m_1, m_2, K_1, K_2. With $\Phi_1(t_{i,c})=0$ and $\Phi_2(t_{i,c})=0$, K_2 becomes: $K_2=m_1V_1(t_{i,c})-m_2V_2(t_{i,c})$

Returning to 6.5(viii$_b$). $\Delta T(t)_{1,c}=\frac{1}{2m_1}\Delta\Phi_1^2(t)=\frac{1}{2}m_1\Delta U^2_{rms}(r_1(t))$, $\Delta T(t)_{2,c}=\frac{1}{2m_2}\Delta\Phi_2^2(t)=\frac{1}{2}m_1\Delta U^2_{rms}(r_2(t))$

$-\Delta V(t)_{1,c}=\frac{m_1^2H}{r_{1,i}}(\frac{r_{1,i}-r_1(t)}{r_1(t)})\doteq\frac{m_1^2H}{r_{1,i}^2}(r_{1,i}-r_1(t))$, $-\Delta V(t)_{2,c}=\frac{m_2^2H}{r_{2,i}}(\frac{r_{2,i}-r_2(t)}{r_2(t)})\doteq\frac{m_2^2H}{r_{2,i}^2}(r_{2,i}-r_2(t))$ and writing out 6.5(viii$_b$) yields:

6.5(x$_b$) $\frac{1}{2m_1}\Phi_1^2(t)=\frac{m_1^2H}{r_{1,i}}(\frac{r_{1,i}-r_1(t)}{r_1(t)})=\frac{1}{2m_2}\Phi_2^2(t)=\frac{m_2^2H}{r_{2,i}}(\frac{r_{2,i}-r_2(t)}{r_2(t)})$

And in particular,

6.5(x$_c$) $\Phi_2(t)=\pm[2\frac{m_2^3H}{r_{2,i}}(\frac{r_{2,i}-r_2(t)}{r_2(t)})]^{\frac{1}{2}}=\pm[2\frac{m_2m_1^2H}{r_{1,i}}(\frac{r_{1,i}-r_1(t)}{r_1(t)})]^{\frac{1}{2}}$ And $\Phi_1(t)=\pm(\frac{m_1}{m_2})^{\frac{1}{2}}\Phi_2(t)$ And

$\frac{m_1^2H}{r_1(t)}-\frac{m_2^2H}{r_2(t)}=\frac{m_1^2H}{r_{1,i}}-\frac{m_2^2H}{r_{2,i}}=K_3$=const.

6. Creation of a Solid Mass Photon-Energetics of a Tungsten Filament Light Bulb

Photons are hypothesized to be solid mass particles produced as collision products of two atoms. Two colliding solid mass atoms, fig. 6.2, compress the atomic mass surface at the contact point resulting in the creation of a Percussive Wave followed by a Shear Wave.

1. Percussive Wave (PW). The collision generated PW with percussive wave speed V_p fans out along the surface of the atom from the contact point at A and re converges at point B directly opposite the contact point A, as labeled in figure 6.2-1. It is helpful to remember that the atoms in a transition metal solid strike one another with frequency $\approx 10^{14}$/sec, the molecules in a liquid $\approx 10^{12}$/sec, and the molecules in a gas at S.T.P.$\approx 10^{9}$/sec.
Let E_{pw} represent the total percussive wave energy generated on the surface of atom #1 by collision with atom #2. It is hypothesized that there exists an atomic species dependent threshold energy E_{Th_P} such that:

a. If $E_{pw} \geq E_{Th_P}$ the PW will compress the photon mass m_{ph} at point B as in Fig. 6.2-2 and 3.

b. If $E_{pw} < E_{Th_P}$ the PW will not compress the photon mass m_{ph} at point B and E_{pw} will travel back and reconverge at point A.

2. Shear wave (SW). The SW fans out along the surface of the atom starting from the contact point at A with shear wave speed V_s and re converges at point B directly opposite the contact point as labeled in figure 6.2-4. Typically for macroscopic material solids, $2 \leq (\frac{V_p}{V_s})^2 \leq 3$ and it is hypothesized that for the solid mass atom, $2 \leq (\frac{V_p}{V_s})^2 \leq 3$ also holds.
Let E_{sw} represent the total shear wave energy generated on the surface of atom #1 by collision with atom #2. It is hypothesized that there exists an atomic species dependent threshold energy E_{Th_S} such that:

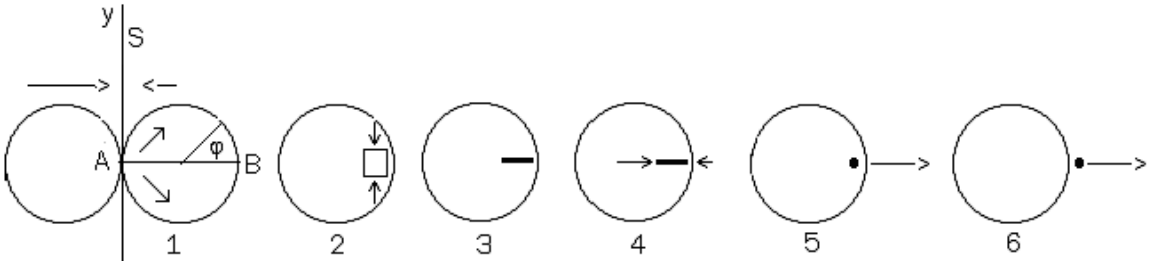
a. If $E_{sw} > E_{Th_S}$ the SW will compress and **accelerate** the photon mass m_{ph} at point A expelling a solid mass photon with translational kinetic energy $\frac{1}{2}m_{ph}v^2$, momentum $m_{ph}\underline{v}$ and binding energy $-\frac{m_{ph}^2 H}{r_{ph}}$. See Fig.6.2-4,5 and 6.

b. If $E_{sw} \leq E_{Th_S}$ the SW will not compress and **accelerate** the photon mass m_{ph} at point A.

To recapitulate: In order to produce a photon with translational kinetic energy $\frac{1}{2}m_{ph}v^2$, momentum $m_{ph}\underline{v}$ and binding energy $-\frac{m_{ph}^2 H}{r_{ph}}$, a collision between atom#1 and atom #2 is required such that atom#1 (The photon emitting atom) is caused to produce shear and percussive wave energies $\frac{1}{2}m_{ph}v^2+\frac{m_{ph}^2 H}{r_{ph}}=E_{pw}+E_{sw}=E_{Th_P}+E_{Th_S}$, where it is assumed that there is a 100% conversion of $E_{pw}+E_{sw}$ to $\frac{1}{2}m_{ph}v^2+\frac{m_{ph}^2 H}{r_{ph}}$ and where $E_{Th_P}+E_{Th_S}=\Delta m_1 C_1$=the change in internal energy of atom #1 due to

collision with atom #2 . The case $\Delta m_1 C_1^2 \gtrless E_{Th_P}+E_{Th_S}$ is discussed below. As regards the temperature dependence of $E_{Th_P}+E_{Th_S}$, see #11 below 6.16. Note that in order to expel the photon with momentum $m_{ph}v\hat{x}$, figure 6.2-4, requires that the shear wave exert a net vector force across the ends of the proto-photon in the $+\hat{x}$ direction. In figure 6.2, the open square represents a right circular cylinder which is the uncompressed mass of the proto- photon with mass m_{ph} and the black circle represents the spherical compressed mass of the photon.

FIGURE 6.2



Atom #2 Atom #1

5A Average Force Between Two Colliding Atoms

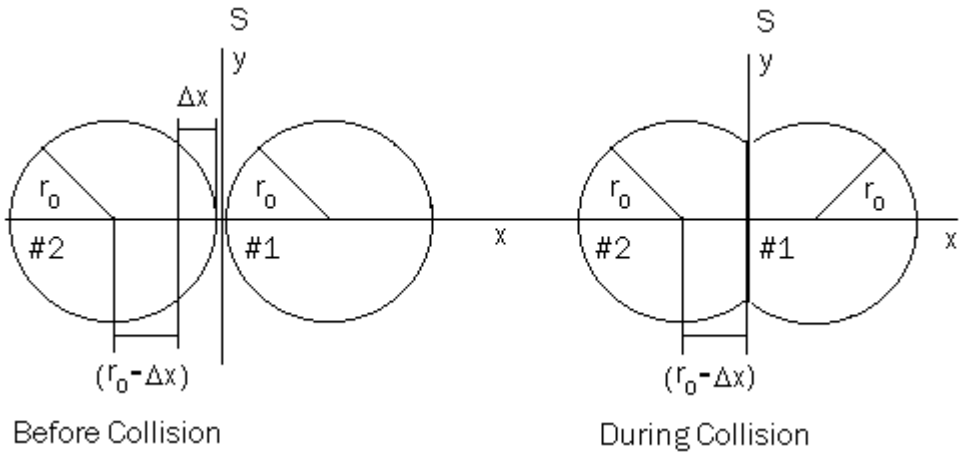
The following analysis proceeds on the assumption that this is the physically correct origin of photons. Consider the magnitude of the average force $|\overline{\underset{\sim}{f}_c}|=\overline{f}_c$ that two colliding atoms exert on one another during the time τ_c that they are in direct contact with one another. See figure 4.10. $\overline{f}_c$ is measured from inertial frame S. Assuming the incident and final velocity of atom #1 is $\underset{\sim}{U}_i=-U_i\hat{x}$ and $\underset{\sim}{U}_f=U_f\hat{x}$ then, $\overline{f}_c$ is: $\overline{f}_c=\frac{\Delta m U}{\Delta t}=\frac{m(U_i+U_f)}{\tau_c}$. Assuming the special case $U_i=U_f=\left[\frac{KT}{2\pi m}\right]^{1/2}$, (No photon creation), $\overline{f}_c$ becomes:

6.6 $$\overline{f}_c=\frac{1}{\tau_c}\left[\frac{2mKT}{\pi}\right]^{1/2}$$

In order to derive the speed of sound formula for the transition metals 4.14, it was assumed in chapter 4, section 3 that $\tau_c << R_o(T)/[\frac{KT}{2\pi m}]^{\frac{1}{2}}$ and consequently: $\overline{f}_c >> \frac{KT}{\pi R_o(T)}$. Evaluating R_o for tungsten using Table 4.1 yields: $R_{o_w}(800^oK)=(8.1)10^{-11}$cm and evaluating the inequalities yields: $\tau_{c_w}\Big|_{T=800^oK} << (1.1)10^{-14}$sec. and $\overline{f}_{c_w}\Big|_{T=800^oK} >> (4.3)10^{-4}$dy.

The average time t_r that it takes two colliding atoms to come to rest is $t_r=\frac{1}{2}\tau_c$ and $t_{r_w}\Big|_{T=800^oK}$ <<$(5.5)10^{-15}$sec. and using $\tau_c=10^{-16}$sec yields: $\overline{f}_{C_w}\Big|_{T=800^oK}=(4.7)10^{-2}$dy. During collision, the distance $|r_o\hat{x}|$ is shortened by $\overline{\Delta x}>0$ to $|(r_o-\overline{\Delta x})\hat{x}|$. Figure 6.3. What is the value of $\overline{\Delta x}$ assuming the de-acceleration is constant ?

FIGURE 6.3



$(\overline{\Delta x})_W=\frac{1}{2}U_i\,t_{r_w}\Big|_{T=800^oK}=\frac{1}{2}[\frac{KT}{2\pi m}]^{\frac{1}{2}}\frac{1}{2}\tau_c=\frac{1}{4}[(0.58)10^8]^{\frac{1}{2}}10^{-16}=(1.9)10^{-13}$cm.

Note that $\overline{f}_C(\overline{\Delta x})=\frac{2mU_i}{\tau_c}(\frac{1}{4}U_i\cdot\tau_c)=\frac{1}{2}m(U_i)^2$ as required.

With p=0 (Constant density), the radius of the proto photon r_{ph_p} is: $r_{ph_p}=(\frac{m_{ph}}{\frac{4}{3}\pi\rho_{ph_p}})^{\frac{1}{3}}$.

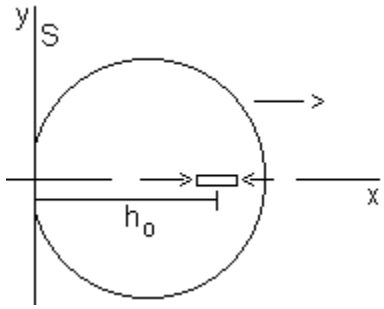
Using 3.4; The surface density of W with p=0 is $35\frac{gm}{cm^3}$ and assuming the density of a proto photon is also 35gm/cm^3 and using $m_{ph}=3.6\cdot10^{-34}$gm (Derived below):

$r_{ph_p}=[\frac{(3.6)10^{-34}}{(1.4)10^2}]^{\frac{1}{3}}=(1.4)10^{-12}$cm= $(1.4)10^{-4}\,^oA$<<r_{At}. Now assume the volume of the proto photon V_{cy_p} is the right circular cylinder in figure 6.2 where $V_{cy_p}=\pi(r_{cy_p})^2L_{cy_p}=2\pi(r_{cy_p})^3$. Assuming $V_{cy_p}=V_{ph_p}$ where V_{ph_p} is the volume of the spherical proto photon (Chapter 6, section 1), $V_{ph_p}=\frac{4}{3}\pi r_{ph_p}^3=\frac{4}{3}\pi(1.4)^3 10^{-36}=(1.1)10^{-35}$cm^3 yields: $r_{cy_p}=(1.2)10^{-12}$ cm., $A_{cy_p}=\pi(1.2)^2 10^{-24}=(4.5)10^{-24}$cm^2, $L_{cy_p}=(3.0)10^{-12}$cm, $V_{cy_p}=(1.1)10^{-35}$cm^3.

Consider atom #1 after it has been struck by atom #2 and is accelerating in the $\hat{x}$ direction. Let $h(h_o,t)_{ph}\hat{x}=[h_o+\chi(h_o,t)]_{ph}\hat{x}$ represent the position of the center of mass of the proto photon with $\chi(h_o,0)=0$. Figure 6.4a shows the position of the proto photon inside the atom as measured from inertial frame S at rest w.r.t. the center of mass of

two colliding atoms #1 and #2 only one of which is shown. At t=0, $\dot{h}(0)_{ph}=0$, $\dot{h}(0^{+})_{ph}>0$ where $\dot{h}(t)_{ph}$ is the speed of the proto photon at time t .

FIGURE 6.4a



$F\hat{x}=f([h_o+\frac{L_{ph}}{2}p+\chi(h_o+\frac{L_{ph}}{2}p,t)]_{ph})\cdot\hat{x}+f([h_o-\frac{L_{ph}}{2}p+\chi(h_o-\frac{L_{ph}}{2}p,t)]_{ph})\cdot\hat{x}$ represents the sum of the forces acting across the yz faces of the proto photon, (See figure 6.4 and 6.2-4),where $f([h_o+\frac{L_{ph}}{2}p+\chi(h_o+\frac{L_{ph}}{2}p,t)]_{ph})\le 0$ and $f([h_o-\frac{L_{ph}}{2}p+\chi(h_o-\frac{L_{ph}}{2}p,t)]_{ph})\ge 0$. From 6.5 $F\hat{x}=m_{ph}\ddot{h}_{ph}\hat{x}$. Expand h_{ph} in a power series in t with $\dot{h}(0)_{ph}=0$, $\ddot{h}(0)_{ph}=0$, $\dddot{h}(0)_{ph}=0$. This yields, $h_{ph}=h_o+a_2t^2+a_4t^4+\ldots$, $a_2>0$ and approximate h_{ph} by $h_{ph}=h_o+a_2t^2$ with $\dot{h}_{ph}=2a_2t+4a_4t^3$, $\ddot{h}_{ph}=2a_2+12a_4t^2$ and $\dddot{h}_{ph}=24a_4t$. Define t_f by $h(t_f)_{ph}=2r_o\doteq h_o+a_2t_f^2$ and $c_f\doteq 2a_2t_f$ and $\ddot{h}_{ph}\doteq 2a_2$. Solve for a_2 and t_f yielding $a_2\doteq\frac{c_f^2}{8r_o(1-\frac{h_o}{2r_o})}$, $t_f\doteq\frac{4r_o(1-\frac{h_o}{2r_o})}{c_f}$, $F=m_{ph}\ddot{h}_{ph}\doteq m_{ph}\frac{c_f^2}{4r_o(1-\frac{h_o}{2r_o})}$.

Table 6.4 lists t_f and F as functions of the initial position h_o of the center of mass of a proto photon for the special case $r_o=(1.3)\,10^{-8}$ cm, (The tungsten atom), at $T=(800)(^{o}K)$. The energy equivalence of $T=(800)(^{o}K)$ is 0.1ev.
A-priori the value of $E_{Th_P}+E_{Th_S}$ is not known. It is assumed that after N collisions with Tungsten atoms ($N\approx 10^6$) the emitted photons are in thermal equilibrium with their parent atoms. Assuming the photon speed at it leaves the atom is $c_f=(3.0)10^{10}\frac{cm}{sec}$, the photon mass is $m_{ph}=(3.6)10^{-34}$gm with binding energy $|BE_{ph}|\ge 0.1$ev. The total energy to produce a photon in thermal equilibrium at $T=(800)(^{o}K)$ is $KE_{ph}+|BE_{ph}|\ge 0.2$ev. In general $c_f\neq(3.0)10^{10}\frac{cm}{sec}$, and $c_{ph_{eq}}=(3.0)10^{10}\frac{cm}{sec}$, is achieved by multiple collisions of the newly created photon with Tungsten atoms and resultant increase in KE_{ph} and decrease in r_{ph} due to compression with resultant increase in $|BE_{ph}|$.

TABLE 6.4

$\frac{h_0}{r_0}$	t_f (sec)	F(dyn)
1	$(8.5)10^{-19}$	$(1.2)10^{-5}$
1.5	$(4.3)10^{-19}$	$(4.8)10^{-5}$
1.9	$(8.5)10^{-20}$	$(1.2)10^{-4}$
1.99	$(8.5)10^{-21}$	$(1.2)10^{-3}$

For an analysis of negligible terms missing in the computation of F(dyn), see sec.13, appendix 6A.

5B Over Pressure Necessary to Compress and Accelerate a Photon

In the above, the force F necessary to accelerate the photon mass from $c_0=0\frac{cm}{sec}$ to c_f from its point of origin within the tungsten atom to the surface of the atom was derived. In what follows an approximate value to the over pressure P necessary to compress the photon from its original volume to its final volume is derived. For ease of computation, two simplifying assumptions are made.

1. The right cylindrical proto photon of fig. 6.4 is replaced by a sphere, see fig. 6.4b, where the initial volume of the sphere, $V|_{t=0}$, is equal to the initial volume of the cylinder; $V|_{t=0}=\frac{4}{3}\pi r_{ph_p}^3 = (1.1)10^{-35}cm^3$. r_{ph_p} is the radius of the spherical proto photon.

2. While in the atom and being compressed from the spherical proto photon into the photon, the spherical proto photon is in time dependent energy equilibrium with itself $\frac{1}{2}\dot{h}^2_{rms}(\underset{\sim}{h})+\Psi(\underset{\sim}{h})=C(t)_2<0$. See fig. 6.4b.

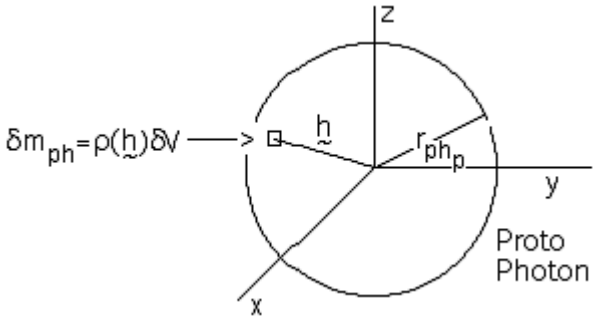
$\underset{\sim}{h}$ is measured from frame S at rest w.r.t. the center of mass of the spherical proto photon where $\underset{\sim}{h}$ is the position of mass element δm within the proto photon where $\underset{\sim}{h}(\underset{\sim}{r},t)=[\underset{\sim}{r}+\underset{\sim}{\chi}(\underset{\sim}{r},t)]$, $\underset{\sim}{\chi}(\underset{\sim}{r},0)=\underset{\sim}{0}$, $0\leq r\leq r_{pph}$. Also, $\rho=\rho(\underset{\sim}{h})$ where $\delta m=\rho(\underset{\sim}{h})\delta V$.

Let P(t) represent the pressure acting in a direction normal to the spherical surface of the proto photon. For a transition metal from 4.6, $PV=\frac{2r_0}{R_0(T)}\frac{NKT}{}$, however for the proto photon there is no empty space in the proto photon analogous to $R_0(T)$ for the transition metals. It is hypothesized that for the proto photon for constants $\gamma>0$ and $K_1>0$: $PV^{\gamma}=K_1$ and $PdV=K_1V^{-\gamma}dV$.

The work done in compressing a spherical proto photon into a spherical photon is

$$\Delta W=-\int_{V_i}^{V_f} PdV = \frac{K_1}{(\gamma-1)}V^{-(\gamma-1)}\Big|_{V_i}^{V_f} = \frac{K_1}{(\gamma-1)}[(V_f)^{-(\gamma-1)}-(V_i)^{-(\gamma-1)}]$$ with $\Delta W>0$. Compiling results:

FIGURE 6.4b



6.7a $$PV^{\gamma}=K_1>0,\quad \Delta W=\frac{P_iV_i}{(\gamma-1)}\left[\left(\frac{V_i}{V_f}\right)^{(\gamma-1)}-1\right],\ \gamma\geq 1,\ \left(\frac{V_i}{V_f}\right)>1$$

6.7b $$\lim_{\gamma\to 1}\Delta W=P_iV_i\ln\left(\frac{V_i}{V_f}\right)$$

Let $P_i=P(0)_W$, $P_f=P(t_f)_W$, and from above, $V_i=V_{ph_p}(0)=(1.1)10^{-35}$ cm^3. Given $T=(800)(^oK)$ with energy equivalence 0.1ev, and assuming that after attaining thermal equilibrium the photon has kinetic energy $KE_{ph}=0.1ev$ with $|BE_{ph}|=0.1ev$ and using table 6.2 the radius of the photon is $r_{ph}(t_f)=(7.7)10^{-25}cm$ with $V_f=V_{ph}(t_f)=(1.9)10^{-72}cm^3$. Using 4.5, $R_o(800)=(8.1)10^{-11}cm$ and using 4.7, $P(0)_W=(2.0)10^{12}\frac{dy}{cm}2$.

Evaluating K_1 for tungsten at t=0: $K_{1_W}=P(0)_W[V_{ph_p}(0)]^{\gamma}=(2.0)10^{12}[(1.1)10^{-35}]^{\gamma}ergcm^{3(\gamma-1)}$.

From 6.7a $$\Delta W=\frac{P_iV_i}{(\gamma-1)}\left[\left(\frac{V_i}{V_f}\right)^{(\gamma-1)}-1\right]=(2.2)10^{-23}\frac{\left[\{(5.8)10^{36}\}^{(\gamma-1)}-1\right]}{(\gamma-1)}\ erg$$

Computed values of ΔW in ev as a function of γ are listed in table 6.5.

TABLE 6.5

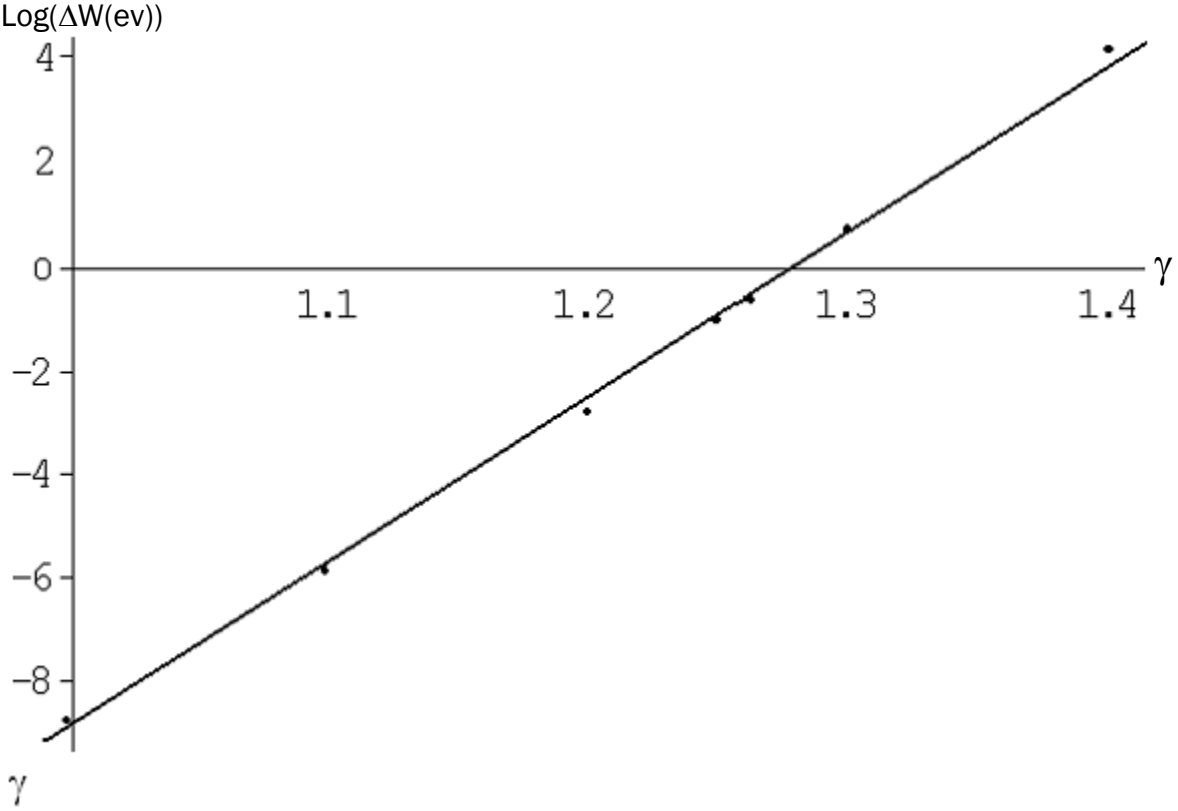
γ	ΔW(ev)	K_{1_W}(erg) $(cm^{3(\gamma-1)})$
1	$(1.2)10^{-9}$	$(2.2)10^{-23}$
1.1	$(6.6)10^{-7}$	$(7.0)10^{-27}$
1.2	$(1.6)10^{-3}$	$(2.2)10^{-30}$
1.252	0.10	$(3.4)10^{-32}$
1.260	0.20	$(1.8)10^{-32}$
1.3	5.0	$(7.2)10^{-34}$
1.4	$(1.8)10^{4}$	$(2.3)10^{-37}$

A graph of ΔW as a function of γ is given in graph 6.1 .
During the creation of a photon inside an atom on the surface of an incandescent tungsten filament, the force and energy necessary to compress a proto photon into a photon come from the initial percussive and shear wave energy $E_{pw_i}+E_{sw_i}$ generated by collision with adjacent atoms in the tungsten filament.
The change in wave energy $\Delta(E_{pw}+E_{sw})$ necessary to produce a photon is $\Delta(E_{pw}+E_{sw})=E_{pw_f}+E_{sw_f}-(E_{pw_i}+E_{sw_i})<0$. Assume the following:

a. At t=0, two identical tungsten atoms with equal translational KE and equal and opposite momenta collide, and all of the KE of atom #2, see fig. 6.2, goes into producing $E_{pw_i}+E_{sw_i}$ in atom #1.

b. All of the initial wave energy $E_{pw_i}+E_{sw_i}$, goes into producing a photon so that $E_{pw_f}+E_{sw_f}=0$.

GRAPH 6.1- Log Plot



$T=(800)(^{o}K)$, $KE_{ph}=0.1ev$, $|BE_{ph}|=0.1ev$, $c_{ph}=(3.0)10^{10}\frac{cm}{sec}$,

Then at the instant τ_o at which atom #1 emits a photon, $V(\bar{\tau_o})_W=V(\bar{\tau_o})_{ph_p}=0$ and using conservation of energy and momentum yields: $\frac{1}{2}m_W V(\tau_o)_W^2=(\frac{m_{ph}}{m_W})(\frac{1}{2}m_{ph}V(\tau_o)_{ph}^2)<<\frac{1}{2}m_{ph}V(\tau_o)_{ph}^2$.

At t=0, the two atoms collide and the translational kinetic energy of atom #2, $KE(0)_W=\frac{1}{2}m_W V(0)_W^2$, goes into creating $E_{pw_i}+E_{sw_i}$ so that $\frac{1}{2}m_W V(0)_W^2=E_{pw_i}+E_{sw_i}$ where:

$E_{pw_i}+E_{sw_i}=\frac{1}{2}m_W V(\tau_o)_W^2+\frac{1}{2}m_{ph} V(\tau_o)_{ph}^2-m_{ph}\Delta C_{1,ph}-m_{ph}\Delta\psi_W \doteq \frac{1}{2}m_{ph} V(\tau_o)_{ph}^2-m_{ph}\Delta C_{1,ph}-m_{ph}\Delta\psi_W$.

Expanding the $m_{ph}\Delta C_{1,ph}$ term: $-m_{ph}\Delta C_{1,ph}=m_{ph}^2 H(\frac{1}{r_{ph_f}}-\frac{1}{r_{ph_p}})\doteq m_{ph}^2 H\frac{1}{r_{ph_f}}$ where r_{ph_f} is the radius of the emitted photon and r_{ph_p} is the radius of the proto photon.

Expanding the $m_{ph}\Delta\psi_W$ term:

$-m_{ph}\Delta\psi_W=-m_{ph}[\psi(r_o)_W-\psi(h_o)_W]=\frac{m_{ph}m_W H}{r_o}[(\frac{1}{p+2})((p+3)-(\frac{h_o}{r_o})^{p+2})-1]$ where h_o is the position of the proto photon at t=0, r_o is the radius of the tungsten atom and $-3<p\leq 0$ where the density $\rho(r)$ of the tungsten atom is $\rho(r)=\frac{(p+3)m_W}{4\pi r_o^3}(\frac{r}{r_o})^p$ with $0\leq r\leq r_o$.

Compiling results:

6.8 $$\frac{1}{2}m_W V(0)_W^2=E_{pw_i}+E_{sw_i}\doteq\frac{1}{2}m_{ph} V(\tau_o)_{ph}^2+\frac{m_{ph}^2 H}{r_{ph_f}}+\frac{m_{ph}m_W H}{r_o}[(\frac{1}{p+2})((p+3)-(\frac{h_o}{r_o})^{p+2})-1]$$

Let $F(t)_T$ represent the total absolute value of the compressive force acting on the (assumed) spherical tungsten proto photon where $F(t)_T=P(t)_W A_{ph_p}(t)$. $A_{ph_p}(t)$ is the total area of the proto photon sphere at time t .

6.9 $$F(t)_T=P(t)_W A_{ph_p}(t)$$

In what follows, an order of magnitude approximation of $F(t)_T$ will be computed. Given that the temperature of an incandescent tungsten filament is $T=(800)(^oK)$ with energy equivalence 0.1ev, assume the following:

a. After emission by the tungsten atom at $t=\tau_f$ and after compression and collision with ~ 10^6 tungsten atoms, the emitted photons have average translational kinetic energy $KE_{ph}=0.1ev$, average binding energy $BE_{ph}=-0.1ev$ and speed $c_{ph_{eq}}=(3)10^{10}\frac{cm}{sec}$. Using $\frac{1}{2}m_{ph}(c_{ph_{eq}})^2=0.1ev$, yields $m_{ph}=(3.6)10^{-34}gm$

b. Using $|BE_{ph}|=\frac{m_{ph}^2 H}{r_{ph_f}}=0.1ev$ yields photon final radius $r(\tau_f)_{ph}=(7.7)10^{-25}cm$, cross sectional area $A(\tau_f)_{ph}=\pi(r(\tau_f)_{ph})^2=(1.8)10^{-48}cm^2$ and volume $V(\tau_f)_{ph}=\frac{4}{3}\pi(r(\tau_f)_{ph})^3=(1.9)10^{-72}cm^3$.

c. Assuming the density of the tungsten atom is constant (p=0), the proto photon at the instant of creation t=0, has the same density as the density of the tungsten atom $\frac{m_w}{\frac{4}{3}\pi(r_o)^3}=35\,\frac{gm}{cm}3=\frac{m_{ph}}{\frac{4}{3}\pi(r_{ph_p})^3}$. Solving for r_{ph_p} yields, $r_{ph_p}=(1.4)10^{-12}$cm, cross sectional area $A(0)_{ph_p}=\pi(r_{ph_p})^2=(6.1)10^{-24}cm^2$ and volume $V(0)_{ph_p}=\frac{4}{3}\pi(r_{ph_p})^3=(1.1)10^{-35}cm^3$.

Compute $P(t)_W$ and $F(t)_T$ using $PV^{\gamma}=K_{1_W}$ and 6.9. With $h_o=2r_o-r(0)_{ph}$ (See figure 6.4), $P(0)_W$ is the average surface pressure on tungsten at t=0. Evaluate $P(0)_W$ using 4.7 at (800)(^oK) with (Using 4.5), $R_o(800)=(8.1)10^{-11}$. This yields:

$P(0)_W=\{\frac{KT}{4r_o^2R_o(T)}\}=(2.0)10^{12}\frac{dy}{cm}2$.

With ΔW=0.2ev and using table 6.5, γ=1.260.

$P(0)_W[V_{ph}(0)]^{\gamma}=(2.0)10^{12}[(1.1)10^{-35}]1.260=(1.8)10^{-32}$ erg$(cm)^{3(\gamma-1)}$

and consequently $P(\tau_f)_W=[(1.8)10^{-32}][(1.9)10^{-72}]-1.260=(4.2)10^{58}\frac{dy}{cm}2$

Tabulated results are listed in table 6.6 .

TABLE 6.6

t	$P(t)_W(\frac{dy}{cm}2)$	$A_{ph}(t)cm^2$	$F(t)_T(dy)$	$V_{ph}(t)cm^3$
0	$(2)10^{12}$	$(6)10^{-24}$	$(1)10^{-11}$	$(1)10^{-35}$
t_f	$(4)10^{58}$	$(2)10^{-48}$	$(8)10^{10}$	$(2)10^{-72}$

5C Light Emission from a Tungsten Filament

Consider how many photons per sec, $\#_{ph}$/sec , are emitted by a tungsten filament in a 100W light bulb. Given the dimensions of the filament, Diameter=$(2.5)10^{-2}$cm , Length=$(3.6)10^2$cm, Surface Area=$\pi DL=28cm^2$. The cross sectional area of a tungsten atom is $(2r_{At})^2=(6.25)10^{-16}cm^2$. The number of atoms on the surface of the filament , $\#_{At}$, is therefore, $\#_{At}=(28)/(6.25)10^{-16}=(4.5)10^{16}$ tungsten atoms. Let a_oP_{in} be the electric power converted to photon kinetic energy per second by the filament where P_{in}=100W=10^9erg/sec=$(6.2)10^{20}$ev/sec , and $0<a_o<1$ as measured from inertial frame S at rest w.r.t. the tungsten filament. Given the temperature of the tungsten filament is 800(^oK) with energy equivalence 0.1ev, the number of photons emitted by the filament per sec is therefore: $\#_{ph}/fil.sec=a_oP_{in}/KE_{ph}=$

$a_o(6.2)10^{20}/(0.10)=(6.2)10^{21}a_o \frac{photons}{fil.sec}$. With a measured efficiency for a tungsten 100W light bulb of a_o= $energy_{out}/energy_{in}=(2.3)10^{-2}$, a 100W bulb emits 2.3W as photons. The $\#_{ph}/fil.sec=(6.2)10^{21}(2.3)10^{-2}=(1.4)10^{20}\frac{photons}{fil.sec}$ and the $\#_{ph}/atomsec=[(1.4)10^{20}]/(4.5)10^{16}=(3.1)10^{3}\frac{photons}{atomsec}$ or $1\frac{photon}{atom}$ every $(3.2)10^{-4}$ sec.

From chapter 4, section 3: Let $\overline{\Delta t}$ represent the average time interval measured from the instant that atom #1 is in contact with atom #2 until the instant that atom #1 is again in contact with atom #2: $\overline{\Delta t}=2\frac{\overline{R(t,T)}}{\overline{U_x(t)}}=2\overline{R(t,T)}[2\pi m]^{1/2}/[KT]^{1/2}$. From 4.5 and chapter 4, reference 1: $\overline{R(t,T)}=R_0(T)=2r_0[\frac{\Delta L(T)}{L_o}-\frac{\Delta L(0)}{L_o}]=(2.5)10^{-8}[.24+.086]10^{-2}=$ $(8.3)10^{-11}$cm. and $\overline{\Delta t}=(17)10^{-11}[2\pi(3.1)10^{-22}]^{1/2}/[(1.4)10^{-14}(8)]^{1/2}=(2.2)10^{-14}$sec. One tungsten atom on the surface of the filament, collides with five of its neighbors at the rate of, $\frac{\#_{col}}{sec}=8/\overline{\Delta t}=(3.6)10^{14}$col.sec^{-1}. Therefore, 1 photon for every tungsten atom is created for every $(3.6)10^{14}(3.2)10^{-4}=(1.2)10^{11}$ collisions, so that in terms of the number of collisions necessary to create one photon, the creation of one photon is a very rare process. Let atom #1 be the atom that releases a photon on collision with atom #2.

At T=800^{o}K, how many of those $(1.2)10^{11}$ collisions does atom #1 have energy sufficient to create one photon, where E_{Cr} is the energy necessary to create one photon with TrKe=$\frac{1}{2}m_{ph}c_f^2$ where c_f is not necessarily equal to $(3)10^{10}\frac{cm}{sec}$. The change in binding energy from proto photon to photon is $\Delta BE_{ph_p}=-\frac{m_{ph}^2 H}{r_{ph}}$ and the energy to create a photon is:

6.10 $$E_{Cr}=\frac{1}{2}m_{ph}c_f^2+\frac{m_{ph}^2 H}{r_{ph}}$$

as measured from inertial frame S. See figure 6.4 . E_{Cr} goes into compressing the photon and accelerating the photon.

Let N represent the number of collisions between atom #1 and its five neighbor atoms and let N_E be the number of those collisions whose result is that atom #1 has kinetic energy $\geq$ E as measured from S' at rest with respect to the tungsten filament. N_E is given by:

6.11 $$N_E=\frac{2N}{\sqrt{\pi}}\int_{\frac{E}{KT}}^{\infty} S^{\frac{1}{2}}e^{-S}dS$$

Let E_{Cr} be the solution of 6.11 with $N_E=1$, $N=(1.2)10^{11}$ and KT=.067ev at $T=800^{o}K$.

6.12 $$1=\frac{2N}{\sqrt{\pi}}\int_{\frac{E_{Cr}}{KT}}^{\infty} S^{\frac{1}{2}}e^{-S}dS$$

This yields E_{Cr}=1.8 ev=$(2.9)10^{-12}$erg. Solving for m_{ph} and BE_{ph} using KE_{ph}=0.1ev and assuming $c_f=(3)10^{10}\frac{cm}{sec}$ yields: $m_{ph}=(3.6)10^{-34}$gm=$(2.1)\ 10^{-10}$amu and $BE_{ph}=-1.7$ev. Solving for r_{ph} using $BE_{ph}=-\frac{m_{ph}^2 H}{r_{ph}}$ yields: $r_{ph}=(4.8)10^{-26}$cm.

For simplicity, consider the collision of two isolated atoms. Let atom #2 and atom #1 be on the x-axis with #2 to the left of #1. At t=0 atom #2 collides with atom #1 at the origin and at $t=t_{ph}$, atom #1 ejects a photon down the positive x-axis as in fig. 6.2 and at time t_s the two atoms separate. The origin is the center of mass of the two atoms. Let $F(s,t)_{W_1}$ represent the sum total of percussive, shear and atomic field forces acting on tungsten atom #1 at time t and point s, on and within atom #1, and let $F(s,t)_{W_2}$ represent the sum total of percussive, shear and atomic field forces acting on tungsten atom #2 at time t and point s, on and within atom #2.
Consider $0<t_{pr,i}<t_{pr,f}<t_{sh,i}<t_{sh,f}\leq t_{ph}< t_s$ where $t_{pr,i}$ is the time at which the percussive wave starts to compress the protophoton and $t_{pr,f}$ is the time at which the percussive wave finishes compressing the protophoton. $t_{sh,i}$ is the time at which the shear wave starts to compress the protophoton and $t_{sh,f}$ is the time at which the shear wave finishes compressing the protophoton. A photon is ejected by atom #1 at t_{ph} and the 2 atoms separate at t_s.
With $0 \leq t \leq t_s$, conservation of momentum yields:

6.13 $$\underset{\sim}{P}(0)_{W_2}+\underset{\sim}{P}(0)_{W_1}=\underset{\sim}{P}(t)_{W_2}+\underset{\sim}{P}(t)_{W_1}+\left\{\int_{V_{W_2}}\int_{0}^{t}\underset{\sim}{F}(s,t)_{W_2}dtds+\int_{V_{W_1}}\int_{0}^{t}\underset{\sim}{F}(s,t)_{W_1}dtds\right\}=$$

$$\underset{\sim}{P}(\bar{t}_{ph})_{W_2} + \underset{\sim}{P}(\bar{t}_{ph})_{W_1} + \underset{\sim}{P}(\bar{t}_{ph})_{ph} + \left\{ \int_{V_{W_2}} \int_{0}^{\bar{t}_{ph}} \underset{\sim}{F}(s,t)_{W_2} dtds + \int_{V_{W_1}} \int_{0}^{\bar{t}_{ph}} \underset{\sim}{F}(s,t)_{W_1} dtds \right\} =$$

$$\underset{\sim}{P}(t_{ph})_{W_2} + \int_{V_{W_2}} \int_{0}^{t_{ph}} \underset{\sim}{F}(s,t)_{W_2} dtds + \underset{\sim}{P}(t_{ph})_{W_1} + \underset{\sim}{P}(t_{ph})_{ph} \doteq \underset{\sim}{P}(t_s)_{W_2} + \underset{\sim}{P}(t_s)_{W_1} + \underset{\sim}{P}(t_s)_{ph}$$

V_{W_2} is the volume of atom #2 and V_{W_1} is the volume of atom #1. The approximation used in the 3rd line of 6.13 and 6.14 assumes that the speed of the photon at $t=t_{ph}$ is much larger that the escape speed from the tungsten atom, $c(t_{ph})_{ph} >> V_{es}$.
Note that the sum of the momenta at t=0 is in the $\hat{x}$ direction and consequently the sum of the momenta for t>0 is also zero and therefore the $\hat{y}$ and $\hat{z}$ components of each of the two integrals in 6.13 is zero.

Conservation of energy yields:

6.14 $$KE(0)_2 + m_2C(0)_2 + KE(0)_1 + m_1C(0)_1 = KE(t)_2 + m_2C(t)_2 + E(t)_{2,W} + KE(t)_1 + m_1C(t)_1 + E(t)_{1,W} =$$

$$KE(\bar{t}_{ph})_2 + m_2C(\bar{t}_{ph})_2 + E(\bar{t}_{ph})_{2,W} + KE(\bar{t}_{ph})_1 + m_1C(\bar{t}_{ph})_1 + E(\bar{t}_{ph})_{1,W} =$$

$$KE(t_{ph})_2 + m_2C(t_{ph})_2 + E(t_{ph})_{2,W} + KE(t_{ph})_1 + m_1C(t_{ph})_1 + \frac{1}{2}m_{ph}c^2(t_{ph})_{ph} + \frac{m_{ph}^2 H}{r_{ph}} \doteq$$

$$KE(t_s)_2 + m_2C(t_s)_2 + KE(t_s)_1 + m_1C(t_s)_1 + \frac{1}{2}m_{ph}c^2(t_s)_{ph} + \frac{m_{ph}^2 H}{r_{ph}}$$

Where $KE(t)_n$ is the translational kinetic energy, $C(t)_n$ is the total internal energy of the n^{th} atom and $E(t)_{n,W}$ is the internal and surface wave energy of the n^{th} atom. The C's are defined by 3.17. It has been tacitly assumed that $KE(0)_1 < |BE_{ph}| < KE(0)_2$ so that atom #2 does not create a photon and atom #1 does create a photon.

Using 6.13 with $m_2 = m_1 = m_{At}$ and assuming that all of the translational KE of atom #2 goes into creation of a photon with speed $c(t_s)_{ph}$:

6.15a $$V(0)_2 = V(0)_1 - V(t_s)_2 + V(t_s)_1 + \left(\frac{m_{ph}}{m_{At}}\right)c(t_s)_{ph}$$

and $V(t_s)_2 = \left(\frac{1}{2}\right)^{\frac{1}{2}} V(0)_1$, $V(t_s)_1 = \left(\frac{1}{2}\right)^{\frac{1}{2}} V(0)_1$, so that:

6.15b $V(0)_2 = V(0)_1 + (\frac{m_{ph}}{m_{At}})c(t_s)_{ph}$, $V(0)_2 > V(0)_1$

And with $KE(0)_2 = E_{Cr}$

6.16 $$\frac{1}{2}m_{At}(V(0)_2^2 \doteq \frac{1}{2}m_{ph}[c(t_s)_{ph}]^2 + \frac{m_{ph}^2 H}{r_{ph}}$$

The central hypothesis as regards photon production: Each element and isotope at temperature T has the potential to produce photons with unique mass m_{ph}, unique radius r_{ph} and unique $c(t_s)_{ph}$: If atom #2 has:

(i) $KE_{2,i} < \frac{m_{ph}^2 H}{r_{ph}}$, No photon is created by atom #1.

(ii) $KE_{2,i} = \frac{m_{ph}^2 H}{r_{ph}}$, 1 photon is created by atom #1 but remains in the atom.

(iii) $\frac{m_{ph}^2 H}{r_{ph}} < KE_{2,I} < \frac{m_{ph}^2 H}{r_{ph}} + \frac{1}{2}m_{ph}[V_{es}]^2$, If $c(t_s)_{ph} < V_{es}$, 1 photon is created by atom #1 but is captured by the atom.

(iv) $KE_{2,I} = \frac{m_{ph}^2 H}{r_{ph}} + \frac{1}{2}m_{ph}[V_{es}]^2$, If $c(t_s)_{ph} = V_{es}$, 1 photon is created by atom #1 and escapes from the atom with $c_{ph}=0$ at infinity in vacuum.

(v) $KE_{2,i} = \frac{m_{ph}^2 H}{r_{ph}} + \frac{1}{2}m_{ph}[c(t_s)_{ph}]^2 > \frac{m_{ph}^2 H}{r_{ph}} + \frac{1}{2}m_{ph}[V_{es}]^2$, 1 photon is created by atom #1 and escapes from the atom with $c_{ph} > 0$ at infinity in vacuum.

(vi) $KE_{2,i} > \frac{m_{ph}^2 H}{r_{ph}} + \frac{1}{2}m_{ph}[c(t_s)_{ph}]^2$, does not occur being superceded by case (v)

If correct, the above hypothesis predicts that atoms at temperature T omit mono energetic photons, however after reflection from ~10^6 atoms, the photons will have a Maxwellian distribution of energies.

As regards (i): The collision between atom #2 and #1 is elastic and the initial kinetic energies are exchanged: $\frac{1}{2}m_{At}V(0)_2^2 = \frac{1}{2}m_{At}V(t_{At})_1^2$ and $\frac{1}{2}m_{At}V(0)_1^2 = \frac{1}{2}m_{At}V(t_{At})_2^2$. The wave pressure P_W created at $\underset{\sim}{A}$ in atom #1, figure 6.2, 1 and 2, is $P(\underset{\sim}{A})_W < B(\underset{\sim}{A})$ where $B(\underset{\sim}{A})$ is the bulk modulus of atom #1 at the location of the protophoton. The pressure is too small to compress the proto photon into a photon.

As regards (ii) through (v): The collision between atom #2 and #1 is not elastic. The wave pressure P_W created at $\underset{\sim}{A}$ in atom #1, is $P(\underset{\sim}{A})_W = B(\underset{\sim}{A})$.

The following are true by hypothesis.

1. All photons in a given spectroscopic line have the same momentum $m_{ph}c_{ph}$ but not necessarily the same energy $\frac{1}{2}m_{ph}c_{ph}^2$.
2. Photons in two different lines have different $m_{ph}c_{ph}$ but may or may not have the same $\frac{1}{2}m_{ph}c_{ph}^2$.
3. All photons in the optical of the same $m_{ph}c_{ph}$ have the same color as determined by a normal human eye but not necessarily the same kinetic energy.
4. All photons in the optical of the same color have the same $m_{ph}c_{ph}$ but not necessarily the same kinetic energy.
5. All photons of the same kinetic energy may have different colors.
6. It follows that two separate lines are of different colors and two separate colors are of different lines.
7. All photons in a given spectroscopic line have the same momentum $m_{ph}c_{ph}$ and will not be separable upon further diffraction using a spectroscopic grating. See figure 6.8.

Considering a tungsten light bulb. Tungsten has 5 stable isotopes and each isotope may have a distinct photon kinetic energy spectrum, however (By hypothesis), all atoms of the same tungsten isotope in a tungsten light bulb emit monoenergetic photons with the same momentum. After ~10^6 collisions, this results in a spectroscopic ally determined continuous energy spectrum with mean kinetic energy $\frac{1}{2}m_{ph}\overline{v_{ph}^2}=\frac{3}{2}KT$. As above, solving for m_{ph} assuming that $v_{ph,rms}=c_o=(3.0)10^{10}\frac{cm}{sec}$, at 800^{o}K yields, $m_{ph}=(3.6)10^{-34}$gm. By direct computation using 6.11, 75% of these photons will have speeds between $0.45c_o$ and $1.3c_o$.
It is predicted that the speed of red light v_R from isotopic-ally pure tungsten is not equal to the speed of violet light v_V from isotopic ally pure tungsten.
The tungsten filament radiates $(1.4)10^{20}\frac{photons}{fil.sec}$ in the optical. The power lost by the filament in the production of $(1.4)10^{20}\frac{photons}{fil.sec}$ is: $P=(1.4)10^{20}E_{Cr}=(1.4)10^{20}\{\frac{1}{2}m_{ph}c_f^2+\frac{m_{ph}^2}{r_{ph}}H\}$.
With E_{Cr}=1.8ev, see 6.12, $P=(1.4)10^{20}(1.8)=(2.5)10^{20}$ev/fil.sec=40W/fil. which means that 60W/fil is transformed into heat +infrared photons. The heat is conducted away from the filament by atomic collisions between the tungsten atoms of the filament and the metal light bulb socket and between the tungsten atoms of the filament and the gas surrounding the filament.

7. Creation of Line Spectrum from Solid Mass Photons

The failure of classical electrodynamicists to derive the energy density spectrum of the electromagnetic energy emitted by a black body, a kaolin clay block, spawned the creation of quantum mechanics. By considering the atom to be an energy

quantized harmonic oscillator, Max Planck in December 1900 derived the energy density spectrum of the electromagnetic energy emitted by a kaolin clay block. In 1910 Niels Bohr derived the wavelengths of the discrete electromagnetic spectrum emitted by excited hydrogen, the Balmer Series, from the Bohr-Rutherford model of the atom. And in 1926, Erwin Schrödinger derived the Balmer Series from Schrödinger's Equation.

Continuing the development of line and continuous spectrum radiation begun in chapter 6, section 5: A given atom has an internal energy IE=IKE+IPE, as measured from inertial frame S at rest w.r.t. the center of mass of the atom emitting the photon, where IKE is the internal kinetic energy and IPE is the internal potential energy. For the case of an isolated atom with radial symmetry and $U_{0_{rms}}^2(r_0)=0$, r_o=const. and using 3.15 and 3.28,

6.17 $$\tfrac{1}{2}U_{0_{rms}}^2(r)+\Psi_0(r)=\Psi_0(r_0)=C_0\doteq -\frac{m_{At}H}{r_0}$$

where the subscript o on U,Ψ and C refers to the $U_{0_{rms}}^2(r_0)=0$ state. For this case, the internal energy IE of the atom is called the internal residual energy IE_{re} as measured from inertial frame S. $IE_{re}=IKE_{re}+V_o=m_{At}C_o$ where IKE_{re} is the internal residual kinetic energy, $IKE_{re}=2\pi\int_0^{r_0} r^2\rho_0(r)U_{0_{rms}}^2(r)dr$ and V_o is the total potential energy, $V_o=4\pi\int_0^{r_0} r^2\rho_0(r)\Psi_0(r)dr$. r_o is tabulated in table 4.1.

For the $U_{rms}^2(h_0)\neq 0$ case assuming radial symmetry, 3.15 becomes: $[\tfrac{1}{2}U_{rms}^2(h)+\Psi(h)]=[\tfrac{1}{2}U_{rms}^2(h_0)+\Psi(h_0)]=C_1\doteq -\frac{m_{At}H}{r_1}$. h_o is the instantaneous radius, and r_1 is the mean atomic radius. For this case, IE=IKE+V=$m_{At}C_1$ where the internal kinetic energy IKE is $IKE=2\pi\int_0^{h_0} h^2\rho(h)\dot{h}_{rms}^2dh$ and $V=4\pi\int_0^{h_0} h^2\rho(h)\Psi(h)dh$. $h=r+\chi(r,t)$, $\chi(r,0)=0$, $0\leq r\leq r_1$, and $h_o\equiv h(r_1,t)=r_1+\chi(r_1,t)$, $\chi(r_1,t)\not\equiv 0$, where $r_1=\bar{h}_0$ and $U_{rms}^2(h_0)=(\dot{h}_{0\,rms})^2\neq 0$. The difference in energy ΔIE between the two states is given by:

6.18 $$\Delta IE=IE-IE_{re}=m_{At}(C_1-C_o)=m_{At}U_{rms}^2(r_1)+\frac{m_{At}^2H}{r_0}\left(1-\frac{r_0}{r_1}\right)$$

As examined in chapter 7, charge, ionization and electric current effects are

hypothesized to be due to $\Delta IE \neq 0$. If $\Delta IE = 0$ then there are no charge, ionization or electric current effects.

The origin of the photons emitted by a solid, liquid or gas is analyzed according to the energy source responsible for the energy $E_{Cr}=\frac{1}{2}m_{ph}c_f^2+\frac{m_{ph}^2 H}{r_{ph}}$ (6.10), necessary to create a photon. The variables that determine the physical properties of the photon are its mass, velocity, and radius and these determine its $m_{ph}c_f$, $\frac{1}{2}m_{ph}c_f^2$ and creation energy $E_{Cr}=\frac{1}{2}m_{ph}c_f^2+\frac{m_{ph}^2 H}{r_{ph}}$.
As used here, the terms “Charged atom” and “Excited Atom” mean an atom in radial oscillation i.e. $\Delta IE \neq 0$. See 6.18.

Line Spectra

Line spectra from metal electrode excited gas in glass tubes have been observed for over 125 years. It is generally assumed that the reported spectra from a glass tube filled with atom X is:
1. Not due to photons emitted by doped atoms Y in the glass of the glass tube.
2. Not due to excitation of the atoms of the glass tube by direct contact with sputtered metal electrode atoms and the subsequent emission of photons by the atoms of the glass.
3. Not due to secondary excitation of the atoms of the gas or the glass by externally applied photon or high frequency sound sources.

In what follows, we will examine the validity of #1 above.

The Balmer Series

The characteristics of the spectra emitted by hydrogen excited by an electric source coupled to the gas through a conducting electrode, depends on the pressure of the gas, the applied voltage, the geometry of the electrode and the geometry of the confining tube. If for example a modern glass tube filled with hydrogen is emitting a continuous spectrum at 20Atms, by decreasing the pressure, the continuous spectrum will resolve into four discrete bands in the visible. On further reduction of pressure, the bands will resolve into four discrete lines in the visible (Red, green, blue, violet). The Ultraviolet portion of the series (A series of lines with decreasing separation distance in the ultraviolet) has as its source, White Dwarf Stars. This is the Balmer Series.
As regards the four discrete lines in the visible. Let S be an inertial frame at rest w.r.t the metal electrodes. Balmer Series photons typically are produced by hydrogen atoms at a temperature of $T \approx 350^{o}K$ with mean KE=0.045 ev.

The red light photons emitted by a tungsten 100W light bulb have $KE_{ph,W}$=0.1 ev with momentum $m_{ph,W}c_o=(1.1)10^{-23}\frac{gm\,cm}{sec}$ and $m_{ph,W}=(3.6)10^{-34}$gm. The momentum of the red light photons emitted by tungsten is by hypothesis equal to the momentum of the Balmer Series red light photons: $p_{ph,W}= p_{ph,H}$ and IF the photons comprising the red line have kinetic energy $KE_{ph,H}$=0.045 ev. their speed $c_{ph,H}$ is $c_{ph,H}=(1.3)10^{10}\frac{cm}{sec}$ with $m_{ph,H}=(8.5)10^{-34}$gm.

It is generally believed that the red light discharge of the tube is due to excitation of the hydrogen gas by electrons emitted from the cathode. This cannot be the case as a continuous luminous discharge producing the Balmer Series can occur in curvilinear tubes where the emitting gas is:
a. separated from both anode and cathode by several layers of glass.
b. not on a line of sight between the two electrodes.
c. is uniform throughout the length of the glass. i.e. there is no cathode glow.

It is hypothesized that the electrodes charge the hydrogen gas by direct contact with the negative electrode and the charge is spread throughout the gas by direct contact between the atoms of the gas. Physically increased charge means increased amplitude of the surface oscillation of the atoms of the gas. When the charge energy on one of the hydrogen atoms in the molecule is E_{Cr} , the hydrogen molecule emits 1 red line photon with momentum $p_{ph,H}=(1.1)10^{-23}\frac{gm\,cm}{sec}$. A-priori neither the speed nor the mass of a red line photon are known and consequently the kinetic energy $KE_{ph,H}$ of a red line photon at this point is not known.
As the red glow is uniform throughout the tube, the hydrogen molecule does not pick up E_{Cr} on one contact with the negative electrode.
The green, blue and violet line photons of the Balmer Series are by hypothesis created by the adsorption of red line photons by metal atoms doped in the glass (Li, Be, Ca) and the subsequent expulsion of green, blue, and violet photons respectively by a process of optical pumping as discussed in chapter 6, section 7. This can be experimentally determined by:
1 Determining chemically whether or not there are doped atoms in the glass used to create the Balmer Series.
2. Construct a Geissler Tube from chemically pure SiO_2 and if the hypothesis is correct, only the red line will be created.

By hypothesis, 1 or more red line photons striking Li atoms produce the green line, 1 or more red line photons striking Be atoms produce the blue line and 1 or more red line photons sriking Ca atoms produce the violet line.

The physical dimensions of the cylindrical glass tube as used in an instructional physics laboratory are $r_{GT}=\frac{1}{\sqrt{\pi}}$ cm, L_{GT}=10cm, V=10cm^3. The H_2 pressure in the tube is 10^{-2}Atm=$10^4\frac{dy}{cm^2}$

and the number of H_2 molecules N_{H_2} is $N_{H_2}=(2.4)\cdot 10^{18}$ computed for $T=300^{o}K$. The radius of H, r_H is: $r_H=(0.51)\cdot 10^{-8}cm$ and the radius of the hydrogen molecule r_{H_2} is $r_{H_2}=(1.0)\cdot 10^{-8}cm$. The mean free path λ of a hydrogen molecule is, $\lambda=\frac{KT}{4\pi r_{H_2}^2 P}$

$=\frac{V}{4\pi r_{H_2}^2 \#_{H_2}}=(3.4)\cdot 10^{-3}cm.$

The temperature of the H_2 gas when emitting in the optical is $\approx 350^{o}K$ and the average speed of the H_2 molecule is $\bar{v}=\left[(2.55)\frac{KT}{m}\right]^{\frac{1}{2}}=(1.9)\cdot 10^{5}\frac{cm}{sec}$. The average time Δt_{H_2} between collisions of H_2 with H_2 is $\Delta t_{H_2}=\frac{\lambda}{\bar{v}}=(1.8)\cdot 10^{-8}$ sec. with collision frequency $f=\frac{1}{\Delta t_{H_2}}=5.6\cdot 10^{7}\frac{col}{sec}$. The radiated power in the optical of a 100W tungsten light bulb is $\doteq$2.2W, and let the radiated power of the red line emitted outside the luminescent glass tube be represented by P_{GT}.

The creation of the Balmer Series red line photons is modeled as follows. Starting with all hydrogen molecules with no excitation energy, at t=0 hydrogen molecule #1 collides with the negative electrode and picks up energy Δe from the negative electrode. $\Delta t_{H_2}=(1.8)\cdot 10^{-8}$sec. later, Δe is transferred by direct collision from Hydrogen molecule #1 to Hydrogen molecule #2. The collision process continues until all molecules in the tube have excitation energy Δe, then $2\Delta e$, then $3\Delta e$ ... until finally all molecules in the tube have $N\Delta e=E_{cr}$ at which time the tube discharges, and all molecules simultaneously emit one red photon with momentum $p_{ph,H}=(1.1)10^{-23}\frac{gm\,cm}{sec}$.

With P_{GT} as above, let Δt_{ep} represent the time interval between the discharge of the tube and the next discharge of the tube: $\Delta t_{ep}=\frac{N_{H_2}\cdot KE_{ph}}{P_{GT}}=\frac{N_{H_2}}{P_{GT}}\left(\frac{1}{2}p_{ph,H}\,c_{ph,H}\right)=(1.3)10^{-5}\left(\frac{c_{ph,H}}{P_{GT}}\right)sec.$

with a repetition rate $f=\frac{1}{\Delta t_{ep}}=(7.7)10^{4}\left(\frac{P_{GT}}{c_{ph,H}}\right)\frac{1}{sec}$. The validity of the expression for Δt_{ep} can be determined by directly measuring Δt_{ep}, $c_{ph,H}$ and P_{GT}: e.g. if $P_{GT}=10^{6}\frac{erg}{sec}$ and $c_{ph,H}=10^{8}\frac{cm}{sec}$ then $\Delta t_{ep}=(1.3)10^{-3}$sec and $f=(7.7)10^{2}\frac{1}{sec}$.

The power in to the tube is represented by $P_{in}\frac{erg}{sec}$. Given the cross section of the electrodes is $1cm^2$, the number of molecules hitting the electrode per second is

$0.25n\bar{v}=(1.1)10^{22}\frac{hits}{sec}$, and each collision takes away $\Delta e=(0.91)10^{-22}P_{in}$ erg. Where $P_{in}=5W=(5)10^{7}\frac{erg}{sec}$: $\Delta e=(4.6)10^{-15}$erg.

The tube is idealized at time t, to consist of N molecules each at the center of a cube of volume $\frac{10}{N}=(4.2)10^{-18}cm^3$, with center to center distance $\Delta x=(1.61)10^{-6}$cm and cross sectional area $(\Delta x)^2=(2.59)10^{-12}cm^2$. $(\Delta x)^2$ on each electrode receives $(1.1)10^{22}(\Delta x)^2=(2.8)10^{10}\frac{hits}{sec}$ with $(3.6)10^{-11}\frac{sec}{hit}$ .and there is a hit in $(\Delta x)^2$ at $t_i=(3.6)10^{-11}i$, with i=0,1,2,... There are $N_1=\frac{10}{\Delta x}=(6.25)10^6$ molecules in a line between the two electrodes. With average speed in a given x direction $\bar{U}_x=[\frac{KT}{2\pi m}]^{\frac{1}{2}}=(4.8)10^{4}\frac{cm}{sec}$, if a molecule leaves the electrode at time t_i with oscillation energy Δe, Δe is approximated to arrive at $L_o-\Delta x(i+\frac{1}{2})$, at arrival time t_{a_i} by $t_{a_i}=t_i+(L_o-\Delta x(i+\frac{1}{2}))(\frac{1}{\bar{U}_x})$ where t_i is the time at which a molecule with oscillation energy Δe leaves the electrode. All N_1 molecules have energy Δe at time $t_{a_{N_1}}=t_{N_1}+(L_o-\Delta x(N_1+\frac{1}{2}))(\frac{1}{\bar{U}_x})\doteq t_{N_1}=(2.25)10^{-4}$sec and $N_T t_{N_1}=\Delta t_{ep}$ for some N_T where $N_T=\frac{\Delta t_{ep}}{t_{N_1}}=(5.9)10^{-2}(\frac{c_{ph,H}}{P_{GT}})$ and with $c_{ph,H}$ and P_{GT} as above, $N_T=6$.

The energy to create 1 photon E_{cr} is given by $E_{cr}=KE_{ph}+|BE_{ph}|\geq 2KE_{ph}=p_{ph,H}c_{ph,H}$ and E_{cr} is also given by $E_{cr}=(\frac{P_{in}}{N_{H_2}})\Delta t_{ep}=(\frac{P_{in}}{P_{GT}})(\frac{1}{2}p_{ph,H}c_{ph,H})\geq p_{ph,H}c_{ph,H}$ with consequent $\frac{P_{in}}{P_{GT}}\geq 2$. With P_{in} and P_{GT} as above, $\frac{P_{in}}{P_{GT}}=50$. Note that with $P_{in}=(5)10^{7}\frac{erg}{sec}$: $E_{cr}=(2.75)10^{-14}$erg and as the energy equivalence of $T=350^oK$ is $(7.2)10^{-14}$erg , $E_{cr}<$ the equilibrium energy of the gas inside the tube. This is not necessarily impossible; See sec.7. If it should turn out that $E_{cr}=(7.2)10^{-14}$erg, with P_{GT} and $c_{ph,H}$ as above, then $P_{in}=(1.3)10^{8}\frac{erg}{sec}=13W$.

As above, the photons comprising the Balmer Series red line have momentum (By hypothesis) equal to that of red light photons emitted by a tungsten 100W light bulb: $p_{ph,H}=m_{ph,H}c_{ph,H}=(1.1)10^{-23}\frac{gm\,cm}{sec}$ and as above with $c_{ph,H}=(1.3)10^{10}\frac{cm}{sec}$: $m_{ph,H}$ equals $m_{ph,H}=(8.5)10^{-34}\frac{gm\,cm}{sec}$, $KE_{ph,H}=0.045$ev and if $|BE_{ph,H}|=KE_{ph,H}$ then $|BE_{ph,H}|=\frac{(m_{ph,H})^2H}{r_{ph,H}}=(7.2)10^{-14}$erg , and $r_{ph,H}$ becomes: $r_{ph,H}=(1.0)10^{-23}$cm

It is assumed that while producing the Balmer Series, the hydrogen remains in (H_2) molecular form. This can be experimentally determined by measuring the change in pressure ΔP of the hydrogen knowing the change in temperature ΔT. With $P_o=\frac{NKT_o}{V_o}$, and $T_o=300^oK$ if the gas disassociates ($H_2 \rightarrow 2H$) as the tube is turned on and the gas starts to emit red light and with $\Delta T=50^oK$, and $\Delta P=\frac{2NK(T_o+\Delta T)}{V_o}-\frac{NKT_o}{V_o}=(4/3)\cdot P_o$. If the gas does not disassociate then $\Delta P=\frac{NK(\Delta T)}{V_o}=(1/6)\cdot P_o$.
Alternatively one can measure the speed of sound in the gas. The speed of sound in molecular hydrogen is $C_o=(\frac{P_o}{\rho_o})^{\frac{1}{2}}=(\frac{KT_o}{2m_H})^{\frac{1}{2}}$. With the tube emitting red light at 350^oK, if the gas disassociates then $C=1.5C_o$ and if the gas does not disassociate then $C=1.1C_o$.

8. Photon Transmission Through a Gas, Liquid or Solid

The mean free path of a photon through a gas at S.T.P. is $\approx 10^4 \mathring{A}$, and through a liquid (e.g. water at S.T.P.) $\approx 1 \mathring{A}$, and through a solid (e.g. the transition metals at S.T.P.) $\approx 1 \mathring{A}$. Consequently if a photon is to go through a gas, liquid or solid, a distance greater than the mean free path, it must go directly through the solid mass atom.
The force on many macroscopic objects in frictional contact with one another (e.g. a boat with initial speed $\dot{h}(0)$, shuts off power at t=0 and drifts to a stop), is given by $f_{Fr}=m\ddot{h}=-K(h)\dot{h}^2$ where K(h)>0. If f_{Fr} is independent of position then K=const.
It is hypothesized that the forces acting on a photon moving in the interior of an atom are given by:

6.19 $$\underset{\sim}{f}_{ph}=m_{ph}\ddot{\underset{\sim}{h}}_{ph}=-g\cdot\dot{h}_{ph}^2\hat{\dot{h}}_{ph}-m_{ph}\nabla\Psi_{At}+\underset{\sim}{f}_{ph,cyl}\ ,\ g=\text{const.}$$

where $\underset{\sim}{f}_{ph}$ is the force acting on the photon, $\underset{\sim}{h}_{ph}(\underset{\sim}{r}_o,O)=\underset{\sim}{r}_o$, $\dot{\underset{\sim}{h}}_{ph}(\underset{\sim}{r}_o,O)=\underset{\sim}{c}(\underset{\sim}{r}_o)$.
$-m_{ph}\nabla\Psi_{At}$ is the atomic field force pulling the photon towards the center of the atom and $\underset{\sim}{f}_{ph,cyl}$ is the force on the photon due to the mass of the cylinder m_{cyl} swept out by the photon as it moves through the atom. See figure 6.5 and 6.6 .
For the special case $\underset{\sim}{h}_{ph}(r_o\hat{x},t)=h_{ph}\hat{x}$, $\underset{\sim}{h}_{ph}(r_o\hat{x},0)=r_o\hat{x}$ with $\dot{\underset{\sim}{h}}(r_o\hat{x},O)_{ph}=-c(r_o)\hat{x}$ and $-r_o\le h(r_o\hat{x},t)_{ph}\le r_o$, and assuming the photon goes through the atom, the frictional term is in the $+\hat{x}$ direction, the atomic field force term is directed toward the center of the atom and the force on the photon due to the mass of the cylinder m_{cyl} is in the $+\hat{x}$ direction. 6.19 becomes:

6.20 $$m_{ph}\ddot{h}_{ph} = g\cdot\dot{h}_{ph}^{2} - m_{ph}\frac{\partial\Psi_{At}}{\partial h_{ph}} + \underset{\sim}{f}_{ph,cyl},$$

A-priori the dominant term(s) on the r.h.s. of 620 is unknown.
In what follows, the influence of each term as if acting alone will be derived.

Assuming the dominant term on the r.h.s of 6.20 is $g\cdot\dot{h}_{ph}^{2}$ and that the photon goes through the atom:

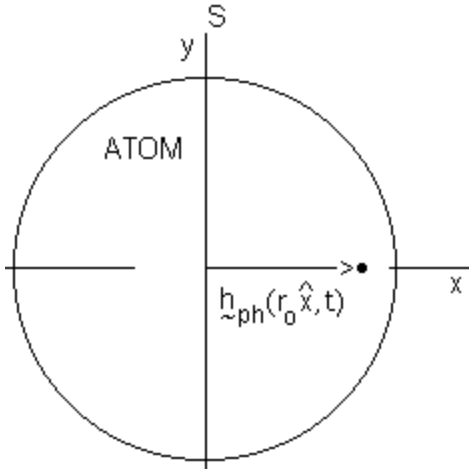
6.21 $$m_{ph}\ddot{h}_{ph} = g\cdot\dot{h}_{ph}^{2},\quad -r_o \le h(r_o\hat{x},t)_{ph} \le r_o\ ,\ h(r_o\hat{x},O)_{ph} = r_o,\ \dot{h}(r_o\hat{x},t)_{ph} \le 0,$$

With solution,
6.21A.

$$h(t)_{ph} = r_o - \frac{m_{ph}}{g}\ln\left(1+\frac{g}{m_{ph}}c(r_o)\,t\right),\quad \dot{h}(t)_{ph} = -\frac{c(r_o)}{\left(1+\frac{g}{m_{ph}}c(r_o)\,t\right)},\quad \ddot{h}(t)_{ph} = \frac{\frac{g}{m_{ph}}c(r_o)^2}{\left(1+\frac{g}{m_{ph}}c(r_o)\,t\right)^2}$$

$$-r_o \le h_{ph} \le r_o\ ,\ h(r_o,0)_{ph} = r_o,\ \dot{h}(r_o,O)_{ph} = -c(r_o) < 0$$

FIGURE 6.5



With g constant, 6.21 can also be written in the alternate form:

6.22 $$\frac{dKE_{ph}}{dh_{ph}} = \frac{2g}{m_{ph}}KE_{ph}\ ,\ KE(r_o)_{ph} = \frac{1}{2}m_{ph}c(r_o)^2\ ,\ -r_o \le h(r_o\hat{x},t)_{ph} \le r_o\ ,\ h(r_o\hat{x},O)_{ph} = r_o,\ \dot{h}(r_o\hat{x},t)_{ph} \le 0$$

With solution:

6.22A $$KE(h)_{ph} = KE(r_o)_{ph}\exp\left\{-\frac{2g}{m_{ph}}r_o\left(1-\frac{h}{r_o}\right)\right\}.$$

The value of g will be derived for a gas, a liquid and a solid neglecting reflection.

g for a Gas

The mean free path of a photon through a gas at S.T.P. is $\approx 10^4$ Å, and through a liquid (e.g. water at S.T.P.) < 1 Å, and through a solid (e.g. the transition metals at S.T.P.) << 1 Å. Consequently if a photon is to go through a gas, liquid or solid, a distance greater than the mean free path, it must go directly through the solid mass atom. Assuming g=const., the value of g is calculated assuming that the photon goes directly through the center of all atoms in its' path.
Consider a solar photon with incident energy 0.1e.v., incident velocity $\underset{\sim}{c}_0 = -c_0\hat{x}$ $c_0=(3)10^{10}$cm/sec and $m_{ph}=(3.6)10^{-34}$gm. See figure 6.6. Assume a pure nitrogen atmosphere where r_0 of N is $r_0=0.75\cdot 10^{-8}$cm. and with mean free path $\lambda=(2.4)10^{-4}$cm. the photon strikes $(4.2)10^3$L atoms in length L where each strike is assumed to go through the center of the atom. What is g for the nitrogen atom assuming that $\frac{KE(-100Km)_{ph}}{KE(r_0)_{ph}} = 0.1$? Using 6.22A, $g=6.6\cdot 10^{-37}$gmcm^{-1}.

g for Liquid Water

Consider the liquid to be water at standard temperature and external pressure 1 atmosphere. The incident photon is as above. Assume all photon atom collisions are between a photon and an oxygen atom where r_0 of O is $r_0=0.73\cdot 10^{-8}$cm. Experimentally the ratio of the light intensity at 200m of pure water to the light intensity at 0m of pure water in still water is $\frac{I(-200m)}{I(r_0)} \doteq 0.1$ and assuming $\frac{KE(-200m)_{ph}}{KE(r_0)_{ph}} \doteq 0.1$ and using 6.22A yields, $g=2.1\cdot 10^{-38}$gmcm^{-1}.

g for a Solid

A solar photon penetrates a copper atom in the radial direction. r_0 of Cu is $r_0=1.1\cdot 10^{-8}$cm. Assuming $\frac{KE(-r_0)_{ph}}{KE(r_0)_{ph}}=\exp -\kappa,\ 0<\kappa\leq\infty$ and using 6.22A, $\exp -\kappa=\exp\left\{-\frac{4g}{m_{ph}}r_0\right\}$. Solve for g, this yields, $g=\frac{m_{ph}\kappa}{4r_0}=0.82\cdot 10^{-26}\kappa\frac{gm}{cm}$.

The Field Force Term

Next consider the influence of the term $m_{ph}\frac{\partial\Psi_{At}}{\partial h_{ph}}$ on $m_{ph}\ddot{h}_{ph}$. i.e. Assume

6.23 $$m_{ph}\ddot{h}_{ph} = -m_{ph}\frac{\partial \Psi_{At}}{\partial h_{ph}}, \quad -r_o \le h_{ph} \le r_o$$

A photon in conformity with 6.23:
(A) Accelerates in the interval $0<h_{ph}\le r_o$, and de accelerates on the interval, $-r_o\le h_{ph}<0$.
(B) Leaves the atom with the same energy $\frac{1}{2}m_{ph}[c(r_o)]^2+m_{ph}\Psi_{At}$ with which it entered.
(C) Does not stop in the interior of the atom.

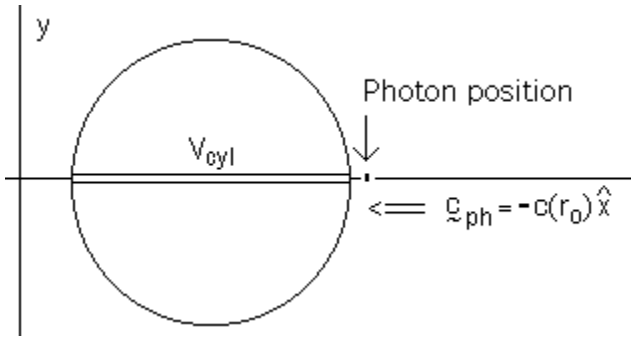
The Ejected Cylinder Term

Next consider the influence of the term $\underset{\sim}{f}_{ph,cyl}$ on $m_{ph}\ddot{h}_{ph}$. i.e. Assume

6.24 $$m_{ph}\ddot{h}_{ph} = \underset{\sim}{f}_{ph,cyl}$$

In the following, it will be shown that for atoms within the domain $-2 \le p \le 0$,
where $\rho_{At}=\frac{(p+3)m_{At}}{4\pi r_o^3}(r/r_o)^p$:
(i) $m_{cyl}<< m_{ph}$
(ii) The total energy E_{cyl} transferred from the photon to m_{cyl} is $E_{cyl}<<\frac{1}{2}m_{ph}[c(r_o)]^2$.
(iii) With incoming $TrKE_{ph}=\frac{1}{2}m_{ph}[c(r_o)]^2$, the f_{cyl} term does not stop the photon on its passage through the atom.
(iii) follows from (ii).

FIGURE 6.6



In order to prove (i): Compute m_{cyl}, figure 6.6, using: $m_{cyl}=\int_{V_{cyl}}\rho_{At}\,dV$ where

$V_{cyl}=\pi r_{ph}^2(2r_o)$ is centered on the center of the atom where radius $r_{ph}=10^{-n_{ph}}$ cm and length $2r_o \approx (2)10^{-8}$cm, is computed by splitting V_{cyl} into:

1. One sphere of radius r_{ph} centered on the center of the atom.
2. Two cylinders each of length $(r_o - r_{ph})$ and radius r_{ph}
3. The volume V* between the sphere and the cylinder of length $2r_{ph}$ and radius r_{ph}

where $V^*=\frac{2}{3}\pi r_{ph}^3$

$$m_{cyl} \doteq \int_{V_{cyl}} \rho_{At}\, dV = \left\{ 4\pi \int_0^{r_{ph}} r^2 \rho_{At}\, dr + 2\pi r_{ph}^2 \int_{r_{ph}}^{r_o} \rho_{At}\, dr + \int_{V^*} \rho_{At}\, dV \right\} \text{ and } \int_{V^*} \rho_{At}\, dV = \frac{2}{3}\pi r_{ph}^3 \rho(R_i)_{At}$$

$\rho(R_i)_{At}$ is the density of the atom evaluated at R_i where R_i is a fixed point in the interval $r_{ph} \le R_i \le 2^{\frac{1}{2}} r_{ph}$. r_{ph} is the minimum value of R, and $2^{\frac{1}{2}} r_{ph}$ is the maximum value of R where R is the distance between the center of the sphere and an arbitrary point in V*. Thinking of R as a variable: $M(R) \equiv \left\{ 4\pi \int_0^{r_{ph}} r^2 \rho_{At}\, dr + 2\pi r_{ph}^2 \int_{r_{ph}}^{r_o} \rho_{At}\, dr + \frac{2}{3}\pi r_{ph}^3 \rho(R)_{At} \right\}$

where $M(2^{\frac{1}{2}} r_{ph}) < m_{cyl} < M(r_{ph})$. The equality $m_{cyl}=M(R_i)$ holds for some R_i, $r_{ph} < R < 2^{\frac{1}{2}} r_{ph}$. Evaluating $M(R_i)$ using $\rho_{At}=\frac{(p+3)m_{At}}{4\pi r_o^3}(r/r_o)^p$ yields:

$$m_{cyl}=m_{At}(p+3)\left\{ \frac{1}{(p+3)}\left(\frac{r_{ph}}{r_o}\right)^{(p+3)} + \frac{1}{2(p+1)}\left[1-\left(\frac{r_{ph}}{r_o}\right)^{p+1}\right]\left(\frac{r_{ph}}{r_o}\right)^2 + \frac{1}{6}\left(\frac{R_i}{r_o}\right)^p \left(\frac{r_{ph}}{r_o}\right)^3 \right\}$$

Using $r_{ph}=(7.7)10^{-25}$cm, see table 6.2, and $r_o=(1.1)10^{-8}$cm and $-3 < p \le 0$, it can be shown that to one significant digit, m_{cyl} becomes:

6.25 $$m_{cyl} \doteq m_{At}(p+3)\left\{ \frac{1}{(p+3)}\left(\frac{r_{ph}}{r_o}\right)^{(p+3)} + \frac{1}{2(p+1)}\left[1-\left(\frac{r_{ph}}{r_o}\right)^{p+1}\right]\left(\frac{r_{ph}}{r_o}\right)^2 + \frac{1}{6}\left(\frac{r_{ph}}{r_o}\right)^{(p+3)} \right\}$$

For $m_{At}=10^2$amu and $m_{ph}=10^{-10}$amu : $\frac{m_{cyl}}{m_{ph}} = \frac{m_{At} m_{cyl}}{m_{ph} m_{At}} = 10^{12}\frac{m_{cyl}}{m_{At}}$. Using 6.25, evaluate $\frac{m_{cyl}}{m_{At}}$. Table 6.5 lists computed values of $\frac{m_{cyl}}{m_{At}}$ and $\frac{m_{cyl}}{m_{ph}}$ to one significant digit .

At t=0, a photon with kinetic energy $\frac{1}{2}m_{ph}c(r_o)^2$ and momentum $m_{ph}\underline{c}(r_o) = -m_{ph}c(r_o)\hat{x}$,

$c(r_o)>0$, strikes an atom (Figure 6.6). For $m_{cyl}<<m_{ph}$ the energy transferred to the cylinder is $\frac{1}{2}m_{cyl}[2c(r_o)]^2+|BE_{cyl}|$.

In order to prove (ii) it must be proved that $\frac{E_{cyl}}{KE_{ph}}=\frac{\frac{1}{2}m_{cyl}[2c(r_o)]^2+|BE_{cyl}|}{KE_{ph}}<<1$.

For $m_{cyl}<<m_{ph}$; $\frac{KE_{cyl}}{KE_{ph}}=\frac{\frac{1}{2}m_{cyl}[2c(r_o)]^2}{\frac{1}{2}m_{ph}[c(r_o)]^2}=4\frac{m_{cyl}}{m_{ph}}$. Table 6.7 lists computed values of $\frac{KE_{cyl}}{KE_{ph}}$ to one significant digit. $|BE_{cyl}|$, $\frac{|BE_{cyl}|}{KE_{ph}}$ and $\frac{E_{cyl}}{KE_{ph}}$ are computed below.

The binding energy BE_{cyl} of the cylinder of volume $V_{cyl}=\pi r_{ph}^2(2r_o)$ centered on the center of the atom where radius $r_{ph}\approx(7.7)10^{-25}$cm and length $2r_o\approx(2.2)\cdot10^{-8}$cm, is computed by splitting V_{cyl} into:

TABLE 6.7

p	$\frac{m_{cyl}}{m_{At}}$	$\frac{m_{cyl}}{m_{ph}}$	$\frac{KE_{cyl}}{KE_{ph}}$	$\lvert BE_{cyl}\rvert$(ev)	$\frac{\lvert BE_{cyl}\rvert}{KE_{ph}}$	$\frac{E_{cyl}}{KE_{ph}}$
0	$7\cdot10^{-33}$	$7\cdot10^{-21}$	$3\cdot10^{-20}$	$3\cdot10^{-24}$	$3\cdot10^{-23}$	$3\cdot10^{-20}$
-1	$2\cdot10^{-31}$	$2\cdot10^{-19}$	$8\cdot10^{-19}$	$1\cdot10^{-22}$	$1\cdot10^{-21}$	$8\cdot10^{-19}$
-1.5	$2\cdot10^{-24}$	$2\cdot10^{-12}$	$8\cdot10^{-12}$	$1\cdot10^{-15}$	$1\cdot10^{-14}$	$8\cdot10^{-12}$
-2	$1\cdot10^{-16}$	$1\cdot10^{-4}$	$4\cdot10^{-4}$	$2\cdot10^{-7}$	$2\cdot10^{-6}$	$4\cdot10^{-4}$
-2.5	$1\cdot10^{-8}$	$1\cdot10^{4}$	0+	30	3	3
-3^+	1	$1\cdot10^{12}$	0+	$6\cdot10^{9}$	$6\cdot10^{8}$	$6\cdot10^{8}$

1. One sphere of radius r_{ph} centered on the center of the atom.
2. Two cylinders each of length (r_o-r_{ph}) and radius r_{ph}
3. The volume V* between the sphere and the cylinder of length $2r_o$ and radius r_{ph}

$$BE_{cyl}=\int_V \rho_{At}\left(\tfrac{1}{2}U_{rms}^2+\Psi_p\right)dV \doteq \left\{4\pi\int_0^{r_{ph}} r^2\rho_{At}\left(\tfrac{1}{2}U_{rms}^2+\Psi_p\right)dr+2\pi r_{ph}^2\int_{r_{ph}}^{r_o}\rho_{At}\left(\tfrac{1}{2}U_{rms}^2+\Psi_p\right)dr+\int_{V^*}\rho_{At}\left(\tfrac{1}{2}U_{rms}^2+\Psi_p\right)dV^*\right\}$$

V* as above and using $\left(\tfrac{1}{2}U_{rms}^2+\Psi_p\right)=C_1=-\frac{m_{At}H}{r_o}$

$$BE_{cyl} = C_1\int_V \rho_{At}\,dV \doteq \left\{4\pi C_1\int_0^{r_{ph}} r^2\rho_{At}\,dr + 2\pi r_{ph}^2 C_1\int_{r_{ph}}^{r_o}\rho_{At}\,dr + C_1\int_{v^*}\rho_{At}\,dV^*\right\}.$$ Evaluate BE_{cyl}.

The last integral is evaluated as above.

6.26 $$BE_{cyl} = -\frac{m_{At}^2 H}{r_o}\left\{\left(\frac{r_{ph}}{r_o}\right)^{p+3} + \frac{1}{2}\left(\frac{r_{ph}}{r_o}\right)^2\frac{(p+3)}{(p+1)}\left[1-\left(\frac{r_{ph}}{r_o}\right)^{p+1}\right] + \frac{1}{6}(p+3)\left(\frac{r_{ph}}{r_o}\right)^{(p+3)}\right\}$$

Table 6.7 lists computed values of $|BE_{cyl}|$ and $\frac{E_{cyl}}{KE_{ph}}$ to one significant digit using the same values for the constants as above. Using table 6.7, $\frac{E_{cyl}}{KE_{ph}} << 1$ for $-2 \le p \le 0$, as to be shown. See (ii) following 6.24. In order to hold the atom together $\nabla\Psi_{At} \neq 0$ so that even if the field force $-m_{ph}\nabla\Psi_{At}$ is $0<|-m_{ph}\nabla\Psi_{At}|<\varepsilon$ with $\varepsilon>0$ arbitrarily small and frictional force=0; for $-2 \le p \le 0$, the incoming photon has sufficient KE_{ph} to enter and exit the atom along a radius with essentially unchanged KE_{ph}.

Assume now that the atom has the actual measured field force so that the absolute value of the difference in potential energy between a photon at the center of the atom and a photon on the surface of the atom is $|\Delta\Phi_{ph}| = |\Phi_{ph}(0) - \Phi_{ph}(r_o^-)| = m_{ph}m_{At}\frac{H}{r_o}\frac{1}{(p+2)}$ for $-2 < p \le 0$ and $|\Delta\Phi_{ph}| = +\infty$ for $-3 < p \le -2$.

Using $m_{ph}=10^{-10}$amu, $m_{At}=10^2$ amu, $H=1\cdot10^{30}\frac{ergcm}{gm^2}$ and $r_o=10^{-8}$cm, $|\Delta\Phi_{ph}|$ becomes: $|\Delta\Phi_{ph}| \approx \frac{10^{-18}}{(p+2)}$ erg $\approx \frac{10^{-6}}{(p+2)}$ ev $>> |BE_{cyl}|$ for $-2 < p \le 0$ and $|\Delta\Phi_{ph}| = +\infty >> |BE_{cyl}|$ for $-3 < p \le -2$ see table 6.7.

Therefore for $-3 < p \le 0$, a photon AT REST on the surface of an isolated atom and with frictional force=0, has sufficient potential energy to displace and break apart m_{cyl}, and sink into the atom and oscillate back and forth losing $|BE_{cyl}|$ on each pass.

Returning now to the general case 6.20. 6.27A and B lists the force equations for a small mass photon impinging on the solid mass atom at t=0. See figure 6.8 with $h(t)_{ph}$ measured from the center of mass of the atom.

6.27A $$m_{ph}\ddot{h}(0)_{ph} = g_{ph}\cdot\dot{h}(0)_{ph}^2 + g_{cyl}\cdot\dot{h}(0)_{cyl}^2 - m_{ph}\frac{\partial\Psi_{At}}{\partial h_{ph}} + f_{ph,cyl},\ t=0,\ h(0)_{ph}=r_o,\ \dot{h}(0)_{ph}=-c_o,$$

Because of the friction term, $\dot{h}(0)_{ph}=\dot{h}(0)_{cyl}$, however for $-2 \le p \le 0$, $m_{cyl}<<m_{ph}$ with consequent $g_{cyl}<<g_{ph}$ and $g_{cyl}\cdot\dot{h}(0)^2_{cyl}$ is therefore dropped from 6.27A.

Evaluating 6.27A for the Cu atom using $m_{Cu}=1.1\cdot10^{-22}$gm, $r_o=1.1\cdot10^{-8}$ cm, $m_{ph}=3.6\cdot10^{-34}$gm (See table 6.1), $c_o=3\cdot10^{10}\frac{cm}{sec}$ and with p=-2 and using Table 6.7: $m_{cyl}=1.1\cdot10^{-38}$gm.

With $\frac{KE(-r_o)_{ph}}{KE(r_o)_{ph}}=\exp-\kappa$, $0<\kappa\le\infty$ and using "g for a solid" above: $g=\frac{m_{ph}\kappa}{4r_o}=0.82\cdot10^{-26}\kappa\frac{gm}{cm}$.

Evaluating $\frac{\partial\Psi_{At}}{\partial h_{ph}}$ at t=0 yields $\frac{\partial\Psi_{At}}{\partial h_{ph}}=\frac{m_{At}H}{r_o^2}$ and 6.27A becomes:

$f(0)_{ph}=7.4\cdot10^{-6}\kappa-3.3\cdot10^{-10}+f_{ph,cyl}$.

Table 6.8 lists $f(0)_{ph}$ as a function of κ and $f_{ph,cyl}$.

TABLE 6.8

κ	$f_{ph,cyl}$(dyn)	$f(0)_{ph}$(dyn)	κ	$f_{ph,cyl}$(dyn)	$f(0)_{ph}$(dyn)	κ	$f_{ph,cyl}$(dyn)	$f(0)_{ph}$(dyn)
0	10^{-4}	10^{-4}	1	10^{-4}	$1.07\cdot10^{-4}$	10	10^{-4}	$1.7\cdot10^{-4}$
0	10^{-5}	10^{-5}	1	10^{-5}	$1.7\cdot10^{-5}$	10	10^{-5}	$8.4\cdot10^{-5}$
0	10^{-6}	10^{-6}	1	10^{-6}	$8.4\cdot10^{-6}$	10	10^{-6}	$7.5\cdot10^{-5}$

For t>0, 6.27A becomes:

6.27B. $m_{ph}\ddot{h}_{ph}=g_{ph}\cdot\dot{h}^2_{ph}+g_{cyl}\cdot\dot{h}^2_{cyl}-m_{ph}\frac{\partial\Psi_{At}}{\partial h_{ph}}$, $t>0$, $h(0)_{ph}=r_o$, $\dot{h}(0)_{ph}=-c_o$

$\frac{\partial\Psi_{At}}{\partial h_{ph}}=\frac{m_{At}H}{r_o^2}(\frac{h}{r_o})^{p+1}$, $h(t)_{ph}=r_o+\chi(r_o,t)$, $\chi(r_o,0)=0$,

As above, because of the friction term, $\dot{h}_{ph}=\dot{h}_{cyl}$, however for $-2 \le p \le 0$, $m_{cyl}<<m_{ph}$ with consequent $g_{cyl}<<g_{ph}$ and $g_{cyl}\cdot\dot{h}^2_{cyl}$ is therefore dropped from 6.27B.

Before photon impact, the internal vibration of the cylindrical section cyl., prevents the spherical atom from collapsing cyl. The photon impact shatters cyl. and the internal vibration of the shattered cyl. continue to prevent the collapse of the atom into the cylindrical portion of cyl. still in the atom as cyl. moves through the atom under the impulsive thrust of the incoming photon.

Solve 6.27B using a power series solution of form $h_{ph}=\sum_{n=0}^{\infty} a_n t^n$. This yields:

6.28 For p=0:

$a_o=r_o$, $a_1=-c_o$, $a_2=\frac{1}{2}\{\frac{g}{m_{ph}}c_o^2-A_1\}$, $a_3=\frac{1}{6}c_o\{2\frac{g}{m_{ph}}(-\frac{g}{m_{ph}}c_o^2+A_1)+\frac{A_1}{r_o}\}$,

$a_4=\frac{1}{12}\{\frac{g}{m_{ph}}(-6c_oa_3+4a_2^2)-\frac{A_1}{r_o}a_2\}$, ...

with $A_1=\frac{m_{At}H}{r_o^2}$ and using the atomic constants for Cu: $A_1=2.9\cdot10^{27}\frac{cm}{sec^2}$ and with

$m_{ph}=3.6\cdot10^{-34}$gm, $\frac{g}{m_{ph}}$ becomes: $\frac{g}{m_{ph}}=2.3\cdot10^{7}\kappa\frac{1}{cm}$, where as above $\frac{KE(-r_o)_{ph}}{KE(r_o)_{ph}}=\exp-\kappa$.

Compute the numerical value of the a_n's and using the above power series evaluate $h_{ph}(t)$, $v_{ph}(t)$. See table 6.9A.

p=0 TABLE 6.9A

κ_{cu}	t sec	$h_{ph}(t)$ cm	$v_{ph}(t)\ \frac{cm}{sec}$
1	0	$1.1\cdot10^{-8}$	$-3.0\cdot10^{10}$
1	$2.0\cdot10^{-19}$	$0.53\cdot10^{-8}$	$-2.7\cdot10^{10}$
1	$4.08\cdot10^{-19}$	0^{+}	$-2.5\cdot10^{10}$
1	$5.3\cdot10^{-19}$	$-0.29\cdot10^{-8}$	$-2.3\cdot10^{10}$
1	$9.2\cdot10^{-19}$	$-1.1\cdot10^{-8}$	$-1.8\cdot10^{10}$

For κ >1 one must evaluate a_5, a_6, ...

using the atomic constants for N: $A_1=4.1\cdot10^{23}\frac{cm}{sec^2}$ and with $m_{ph}=3.6\cdot10^{-34}$gm

and $g=6.6\cdot10^{-37}$gmcm^{-1}, (See "g for a gas" above), $\frac{g}{m_{ph}}$ becomes: $\frac{g}{m_{ph}}=1.8\cdot10^{-3}=2.3\cdot10^{7}\kappa\frac{1}{cm}$. Solve for κ, $\kappa=0.78\cdot10^{-10}$.

p=0 TABLE 6.9B

κ_N	t sec	$h_{ph}(t)$ cm	$v_{ph}(t)\ \frac{cm}{sec}$
$0.78\cdot10^{-10}$	0	$0.75\cdot10^{-8}$	$-3.0\cdot10^{10}$
$0.78\cdot10^{-10}$	$2.0\cdot10^{-19}$	$0.15\cdot10^{-8}$	$v_{ph}(0)^{-}$
$0.78\cdot10^{-10}$	$2.5\cdot10^{-19}$	0^{+}	$v_{ph}(0)^{--}$
$0.78\cdot10^{-10}$	$3.5\cdot10^{-19}$	$-0.30\cdot10^{-8}$	$v_{ph}(0)^{---}$
$0.78\cdot10^{-10}$	$5.0\cdot10^{-19}$	$-0.75\cdot10^{-8}$	$-3.0\cdot10^{10}(1-0.39\cdot10^{-10})$

Using 6.28, compute the numerical value of the a_n's and using the above power series evaluate $h_{ph}(t)$, $v_{ph}(t)$. See table 6.9B.

In general due to contact between the moving solid mass photon and the sides of the cylinder with radius r_{ph} (See figure 6.6), $g \neq 0$. The photon loses kinetic energy, the atom gains shear wave energy, percussive wave energy, internal energy (internal kinetic +potential energy) and translational kinetic energy .
Let SWE≡shear wave energy, PWE≡percussive wave energy, TrKE≡ translational kinetic energy of the atom and $m_{At}C_1$≡internal energy of the atom. Using 6.22:

6.29 $\frac{dKE_{ph}}{dh_{ph}} = -\left(\frac{dSWE}{dh_{ph}} + \frac{dPWE}{dh_{ph}} + \frac{dTrKE}{dh_{ph}} + m_{At}\frac{dC_1}{dh_{ph}}\right) = \frac{2g}{m_{ph}}KE_{ph}$, With $dh_{ph}<0$,

A special solution of 6.29 is examined in the following. In analogy with internal waves in a density stratified fluid, it is assumed that for $\left|\frac{d\rho_{At}}{dh_{ph}}\right|$ sufficiently larger than 0, $\left|\frac{dPWE}{dh_{ph}} + \frac{dTrKE}{dh_{ph}} + m_{At}\frac{dC_1}{dh_{ph}}\right| << \left|\frac{dSWE}{dh_{ph}}\right|$ so that 6.29 becomes:

6.30 $m_{ph}\ddot{h}_{ph} = \frac{dKE_{ph}}{dh_{ph}} = -\frac{dSWE}{dh_{ph}} = \frac{2g}{m_{ph}}KE_{ph}$

A photon with given m_{ph} , $c(r_o)$, initial kinetic energy $KE(r_o)_{ph}=\frac{1}{2}m_{ph}c(r_o)^2$ and momentum $\underset{\sim}{p}(r_o)_{ph} = -m_{ph}c(r_o)\hat{x}$ at $\underset{\sim}{h}(r_o,0)_{ph} = r_o\hat{x}$, strikes the atom at t=0. A shear wave starts at the point $h(r_o,t)_{ph}\hat{x}$ at time t, $0 \le t \le t_o$, $\underset{\sim}{h}(r_o,t_o)_{ph} = \underset{\sim}{0}$ and fans out over 4π sterradians along the isopycnal surface (is.) with radius $h(r_o,t)_{ph}$ following a great circle route traveling along the given isopycnal with average shear wave speed $v_{S_{is}} = v(h(r_o,t)_{ph})_{S_{is}}$. At time $t+\Delta t$, the shear waves generated at $h(r_o,t)_{ph}\hat{x}$ meet at $-h(r_o,t)_{ph}\hat{x}$ where $\Delta t = \frac{(2n+1)\pi h(r_o,t)_{ph}}{v(h(r_o,t)_{ph})_{S_{is}}}$, $0 \le t \le t_o$, and $\Delta t = 0 = \frac{(2n+1)\pi h(r_o,t_o)_{ph}}{v(h(r_o,t_o)_{ph})_{S_{is}}}$ with n=0,1,2,... .

6.31 If the shear wave energy generated at $h(r_o,t)_{ph}\hat{x}$ meets the photon at $h(r_o,t+\Delta t)_{ph}\hat{x} = -h(r_o,t)_{ph}\hat{x}$ for some n, and if the shear wave constructively adds its energy to the energy of the photon, then $\Delta t = 2(t_o - t)$ and the photon emerges from the atom at $h(r_o,2t_o)_{ph}\hat{x} = -h(r_o,0)_{ph}\hat{x} = -r_o\hat{x}$ with kinetic energy $KE(-r_o)_{ph} = \frac{1}{2}m_{ph}c(r_o)^2 = KE(r_o)_{ph}$ at time $t=2t_o$.

Equating the Δt 's:

6.32 $$v(h(r_o,t)_{ph})_{S_{is}}=\frac{(2n+1)\pi h(r_o,t)_{ph}}{2(t_o-t)}\ ,\ \text{for some n},\ 0\le t\le t_o$$

Solving 6.22A for g: $\frac{KE(0)_{ph}}{KE(r_o)_{ph}}=\exp -\kappa=\exp\{-\frac{2g}{m_{ph}}r_o\}$. With $0<\kappa\le\infty$, g is: $g=\frac{m_{ph}\kappa}{2r_o}$

and with $m_{ph}=(3.6)10^{-34}$gm and $r_o=1.1.10^{-8}$cm, g becomes: $g=1.6.10^{-26}\kappa\frac{gm}{cm}$..
Using 6.21A, the time dependent solution to 6.30 is:
6.33 A.

$$h(t)_{ph}=r_o-\frac{m_{ph}}{g}\ln(1+\frac{g}{m_{ph}}c(r_o)t)\ ,\ \dot{h}(t)_{ph}=-\frac{c(r_o)}{(1+\frac{g}{m_{ph}}c(r_o)t)}\ ,\ \ddot{h}(t)_{ph}=\frac{\frac{g}{m_{ph}}c(r_o)^2}{(1+\frac{g}{m_{ph}}c(r_o)t)^2}$$

$$0\le h(t)_{ph}\le r_o\ ,\ 0\le t\le t_o,\ h(0)_{ph}=r_o,\ \dot{h}(0)_{ph}=-c(r_o)<0,\ g=\frac{m_{ph}\kappa}{2r_o}$$

$$h(t_o)_{ph}=0,\ t_o=\frac{m_{ph}}{g\,c(r_o)}\{\{\exp(\frac{r_o g}{m_{ph}})\}-1\},\ \dot{h}(t_o)_{ph}=-c(r_o)\exp(-\frac{r_o g}{m_{ph}})$$

B. $h(2t_o-\tau)_{ph}=-h(\tau)_{ph},\ \dot{h}(2t_o-\tau)_{ph}=\dot{h}(\tau)_{ph},\ \ddot{h}(2t_o-\tau)_{ph}=-\ddot{h}(\tau)_{ph},$

$-r_o\le h(2t_o-\tau)_{ph}\le 0\ ,\ 0\le\tau\le t_o,$

h(t) must satisfy 6.32 and 6.33A. Equating the h(t)'s and solving for $v(h(r_o,t)_{ph})_{S_{is}}$ yields:

6.34 $$v(h(r_o,t)_{ph})_{S_{is}}=\frac{(2n+1)\pi}{2(t_o-t)}\{r_o-\frac{2r_o}{\kappa}\ln(1+\frac{\kappa}{2r_o}c(r_o)t)\}$$

$$\frac{KE(0)_{ph}}{KE(r_o)_{ph}}=\exp-\kappa,\ \ t_o=\frac{2r_o}{c(r_o)\kappa}\{\{\exp(\frac{\kappa}{2})\}-1\},$$

Assume for the moment that the fictitious atomic potential $\psi_f(r)=-\frac{m_{At}H}{r}$ is valid for $0<r<\infty$. Let $v_{f_{es}}$ represent the fictitious escape speed from an atom where $v_{f_{es}}$ is: $v_{f_{es}}=(2\psi(r_o))^{\frac{1}{2}}=(2\frac{m_{At}H}{r_o})^{\frac{1}{2}}$. If the exit speed of a photon, $c(-r_o)$, is $c(-r_o)<v_{f_{es}}$, the photon

is effectively captured by the atom. Using $m_{At}=1.7\cdot10^{-24}\cdot A_o$ gm, $H=1\cdot10^{30}\frac{\text{erg cm}}{\text{gm}^2}$, $r_o=R_1\cdot10^{-8}$ cm where A_o is the atomic mass number and $0.5<R_1<1.6$, $v_{f_{es}}$ becomes: $v_{f_{es}}=1.8\cdot10^{7}(\frac{A_o}{R_1})^{\frac{1}{2}}\frac{\text{cm}}{\text{sec}}$.

Returning to the atomic potential $\psi(r)=-\frac{m_{At}H}{r}$ valid for $0<r\leq r_o$: In order to derive the experimentally determined specific heat C_p (Chapter 5), the field strength $|\psi_{ext}(r_o^+)|$ (Valid for $r>r_o$) evaluated for Pb is $|\psi_{ext}(r_o^+)|=6\cdot10^{-8}|\psi(r_o^-)|$ and consequently $v(r_o^+)_{es}$ (The measured escape speed) is $v(r_o^+)_{es}=2.4\cdot10^{-4}v_{f_{es}}$. See sec. 14, appendix 6B.

9. Optical Pumping, Stimulated Emission, Laser Light

A simple model for the red line output of the first ruby laser is described below. The experimental data are taken from Ref. 6.4.
The first spectroscopic and stimulated emission experiments in the optical were performed on a Cr_2O_3 doped cylindrical Al_2O_3 crystal with length $L_{ru}=1.9$cm and radius $R_{ru}=0.49$cm and volume $V_{ru}=1.4\text{cm}^3$. With a mass of $m_{ru}=5.6$gm and a Cr_2O_3:Al_2O_3 mass ratio of $5.1\cdot10^{-4}$, the ruby crystal contains $1.7\cdot10^{23}$ atoms, $N_{Al}=6.8\cdot10^{22}$Al atoms, $N_O=1.0\cdot10^{23}$ O atoms and $N_{Cr}=2.2\cdot10^{19}$ Cr atoms. The diameter of the Cr atom is $2.36\overset{o}{A}$ and each ruby crystal volume of cross sectional area $\pi(0.49)^2\text{cm}^2$ and length $2.36\overset{o}{A}$ contains $2.8\cdot10^{11}$ Cr atoms.
The ruby cylinder is coated with evaporated silver at each end; one end is opaque and the other is semitransparent with a transmittance of 7%. The photon energy source is a xenon flash lamp emitting green and violet band radiation.
In the following, fig. 11 etc. refers to figures published in Ref. 6.4:
1. Given an electrical energy input per flash of 1.5kilojoules, the stated photon energy output of the flash lamp per flash is $.064\cdot1.5\cdot10^{3}\text{J}=6.0\cdot10^{20}$eV.
2. At time t=0 the flash lamp is turned on and in the time interval $0\leq t<3.5\cdot10^{-4}$sec. the flash lamp emits, $\doteq\frac{3}{8}\cdot6.0\cdot10^{20}=2.2\cdot10^{20}$ev. as photons. Fig. 12.
3. At time $t=3.5\cdot10^{-4}$sec. the ruby begins to emit $2.2\cdot10^{18}$ev. in a red pulse with duration $\doteq1.7\cdot10^{-3}$sec. Fig. 11 and 12.

The following physical model for the laser assumes:
A. The photon output of the flash lamp is adsorbed by Cr atoms and goes through the Al and O atoms essentially unimpeded.

B. The calculated photon mean free path is: $\lambda_{ph}=\frac{1}{\pi r_o^2 n_{Cr}}= 1.4\cdot10^{-4}$cm where λ_{ph} is the mean distance a photon travels between collisions with Cr atoms.

C. The radius of the ruby is R_{ru}=0.49cm. Each flash lamp photon incident on the ruby surface loses energy on passage through each Cr atom in its path and comes to rest inside the crystal. The absorbed photons increase the internal energy and radial oscillation amplitude and therefore generate a new density structure $\rho(r,\theta,\varphi,t)$ in the Cr atoms. By direct contact, the Cr atoms share their energy with neighbor Al, and O atoms, which in turn share their energy with Al, O and Cr atoms throughout the ruby crystal volume.
Let C_1 (3.29) be the average internal energy of the Cr atoms before adsorbing flash lamp photon energy and let $C_1+\varepsilon_{Cr}$ represent the critical energy at which the Cr atom releases a red photon by the process of chapter 6 section 5.

D. The red photon from the laser, (Ls), has a kinetic energy of $ke_{ph,R,Ls}$ (ev) and the average energy $\bar{\varepsilon}_L$ of the green and violet photons emitted by the flash lamp is $\bar{\varepsilon}_L > ke_{ph,R,Ls}$ (ev). It will be remembered that the kinetic energy for a red photon from a tungsten filament, 0.1ev, was derived by assuming that the photons were in thermal equilibrium with the 800^{o}K filament.
The ruby laser is not at 800^{o}K and the emitted red photons may not have energies of 0.1ev. However our assumption is that all red light photons have the same momentum. i.e. Using table 6.1, the momentum of a red photon from a tungsten filament is, equal to the momentum from the red light from the ruby laser.
$m_{ph,R,W}\, c_{ph,R,W}=1.1\cdot10^{-23}\text{gm}\frac{\text{cm}}{\text{sec}}=m_{ph,R,Ls}\, c_{ph,R,Ls}$, where $m_{ph,R,W}$ does not necessarily equal $m_{ph,R,Ls}$ and $c_{ph,R,W}$ does not necessarily equal $c_{ph,R,Ls}$.
With a total energy input of $2.3\cdot10^{20}$eV in $3.5\cdot10^{-4}$sec., by direct computation there are $4.0\cdot10^3\ \frac{ev}{\overset{o}{A}^2}=\frac{4.0\cdot10^3}{ke_{ph,FL}}\ \frac{Ph}{\overset{o}{A}^2}$ incident on the crystal surface in $3.5\cdot10^{-4}$sec. where $ke_{ph,FL}$ is the average ke of a photon emitted by the flash lamp in ev.
With Cr cross section 5.8$\overset{o}{A}^2$, there are on average $\frac{2.3\cdot10^4}{ke_{ph,FL}}$ photons per Cr atom incident on the first Cr atom struck by the flash lamp photons in $3.5\cdot10^{-4}$sec. On average 1 photon per Cr atom incident on the first Cr atom struck by the flash lamp photons occurs every $1.5\cdot10^{-8}ke_{ph,FL}$ sec. for $0<t<3.5\cdot10^{-4}$sec.

E. With the interpretation that oscillation amplitude squared is proportional to "charge" energy, the capacitance of the Cr atom is by hypothesis >> than the capacitance of the Al atom or the O atom: i.e. $C_{Cr}=\frac{Q_{Cr}}{V_{Cr}} >> C_{Al}=\frac{Q_{Al}}{V_{Al}}$ and $C_{Cr}=\frac{Q_{Cr}}{V_{Cr}} >> C_O=\frac{Q_O}{V_O}$

so that under the condition of no energy flow $V_{Cr}=V_O=V_{al}$, the total "charge" energy Q_{Cr} on the Cr atom is $Q_{Cr}>>Q_{Al}$ and $Q_{Cr}>>Q_O$. The energy input to the ruby of $2.3\cdot10^{20}$ev in $3.5\cdot10^{-4}$sec., is stored in the Cr atoms, so that $\frac{2.3\cdot10^{20}}{2.2\cdot10^{19}}$=10ev is stored in each Cr atom as radial oscillation energy.
With a mfp between two adjacent atoms of $10^{-11}<\lambda_{At}<10^{-10}$cm, and with a rms speed v_{At} of $10^4<v_{At}<10^5\frac{cm}{sec}$, the time between collisions is $10^{-16}<\Delta t_c<10^{-14}$sec. The speed v_{ch} at which "Charge" energy moves through the crystal is $v_{ch}\cdot\Delta t_c \doteq 2\cdot10^{-8}$cm and $2\cdot10^6< v_{ch} <2\cdot10^8\frac{cm}{sec}$. The maximum time Δt_M it takes for "charge" energy to pass through the maximum distance with in the crystal is $v_{ch}\cdot\Delta t_M \doteq$2.1cm and $10^{-8}<\Delta t_M<10^{-6}$sec. Thus the charge energy $2.3\cdot10^{20}$ev has ample time to travel from the surface Cr atoms to every Cr atom in the crystal by $t=3.5\cdot10^{-4}$sec.

From chapter 3, section 10 using 3.28, the binding energy of Cr is:
$BE_{Cr}=m_{Cr}C_1=-\frac{m_{Cr}^2H}{r_{Cr}}=-6.4\cdot10^{-7}$erg=-0.40Mev. The oscillation amplitude Δr_{Cr} due to the Cr atom adsorption of 10ev satisfies $10ev=1.6\cdot10^{-11}erg=\frac{m_{Cr}^2H}{r_{Cr}^2}\Delta r_{Cr}$ and $\Delta r_{Cr}=2.9\cdot10^{-13}$cm.

F. At $t=3.5\cdot10^{-4}$sec. the Cr atoms begin to emit red photons. With ε_{Cr} as above, $(\varepsilon_{Cr}-ke_{ph,R,Ls})$ ev goes into compressing a small volume of the Cr atom into a photon by the method of chapter 6, section 5. The resultant photon has a binding energy of $BE_{ph}=-\frac{m_{ph}^2H}{r_{ph}}\cdot(6.24\cdot10^{11})=-(\varepsilon_{Cr}-ke_{ph,R,Ls})$ ev where $c_{ph,R,Ls}$ is not a-priori equal to $3\cdot10^{10}\frac{cm}{sec}$. The total energy emitted as red photons is $N_{ph}\cdot ke_{ph,R,Ls}$ and using Fig 11 with .33J=$2.2\cdot10^{18}$ev yields $N_{ph}\cdot ke_{ph,R,Ls}=2.2\cdot10^{18}$ev.
The red photon energy is released in a pulse of $\doteq1.7\cdot10^{-3}$sec duration whose luminosity decreases exponentially with time. Fig. 12b. The ruby begins to emit at $t=2.8\cdot10^{-4}$sec. at which time every Cr atom has internal energy (C_1+10)ev.

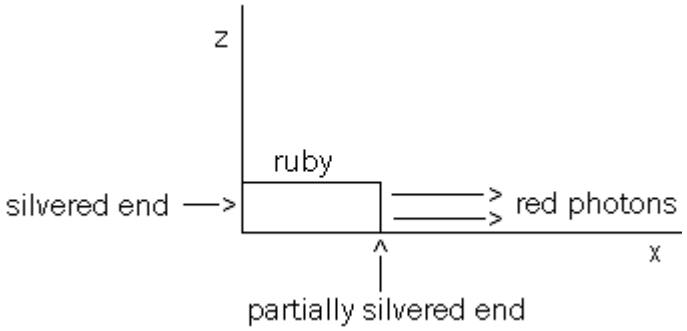
G. At $t=3.5\cdot10^{-4}$sec., N photons with initial velocity $c\hat{x}$ takes $\Delta\tau$ sec to travel a distance L. i.e. $\Delta\tau=\frac{L}{c}$ and $\Delta\tau_n=\frac{2nL}{c}ru$ where n is the number of down and back trips and L_{ru}=length of the ruby. With $c=10^n\frac{cm}{sec}$, L_{ru}=1.9cm: $n=\frac{c\Delta\tau}{2L_{ru}}n=\frac{10^n\Delta\tau}{3.8}n$. The transmittance of the partially silvered mirror is 7% and assuming the reflectivity of

the opposite mirror is 100%, after 66 round trips, $1-(.93)^{66}=99\%$ of the photons generated at $t=3.5\cdot10^{-4}$sec., have been transmitted through the partially silvered end of the ruby in $\Delta\tau_n=\frac{3.8\cdot66}{10^n}=2.5\cdot10^{-n+2}$sec. e.g. With $c=10^8\frac{cm}{sec}$, $\Delta\tau_n$ becomes $\Delta\tau_n=2.5\cdot10^{-6}$sec.

If either one of the two silver coatings on the end of the crystal is removed and replaced by a mirror parallel to and at a distance l_o from the end of the ruby, the time duration of the red pulse increases. This is hypothesized to be due to increasing the optical path length from $2nL_{ru}$ to $2n(L_{ru}+l_o)$ with concomitant increase in $\Delta\tau$ from $\Delta\tau_n=\frac{2nL}{c}ru$ to $\Delta\tau_{n,eff}=\frac{2n}{c}(L_{ru}+l_o)$. See figure 6.7

H. With $\varepsilon_{Cr}=10$ev, then at $3.5\cdot10^{-4}$sec. all $2.2\cdot10^{19}$ Cr atoms emit a photon in a pulse with duration $\Delta\tau_n=2.5\cdot10^{-n+2}$sec. (Sec. G above) at the end of which laser emission ceases for some Δt_1 where $3.5\cdot10^{-4}<\Delta t_1<1.7\cdot10^{-3}$sec. until at time t where $7.0\cdot10^{-4}<t<1.7\cdot10^{-3}$sec., all Cr atoms again would have internal energy (C_1+10)ev. at which time all $2.2\cdot10^{19}$ Cr atoms would emit a second pulse of duration $\Delta\tau_n=2.5\cdot10^{-n+2}$sec.

FIGURE 6.7



This is not observed for reasonable n and therefore ε_{Cr} is $\varepsilon_{Cr}=10(1+\frac{\varepsilon_0}{10})$ev with $\varepsilon_0<<10$ev. From figure 13, the laser output pulse intensity has an oscillatory variation whose frequency decreases from $\approx 5\cdot10^5$ hertz at $6\cdot10^{-4}$ sec. after the onset of oscillation, to $2\cdot10^5$ hertz at $12\cdot10^{-4}$sec. after the onset of oscillation. The decreasing power output of the exciting lamp (fig. 12) provides ε_o ev for ΔN Cr atoms during time Δt where $\Delta N(\tau_1,\Delta t)_{Cr}\doteq-\frac{dN_{Cr}}{dt}\Delta t$, $3.5\cdot10^{-4}<\tau_1<1.7\cdot10^{-3}$sec. for small enough Δt and during time Δt, ΔN_{Cr} Cr atoms emit a red photon after which the ΔN_{Cr} Cr atoms start to adsorb $(10+\varepsilon_o)$ev and repeat the emission process yielding $2\cdot10^{18}$ev in red photons in $1.7\cdot10^{-3}$sec.

I. With $KE_{L,ph}$=kinetic energy of the lamp photon and $KE_{L,ph} << 10+\varepsilon_o=\varepsilon_{Cr}$: If $N_{L,ph}$ lamp photons are adsorbed by a given Cr atom and:

1. If $N_{L,ph}\cdot KE_{L,ph}<\varepsilon_{Cr}$, no laser photons are emitted.

2. If $N_{L,ph}\cdot KE_{L,ph}=\varepsilon_{Cr}$, 1 laser photon is emitted

3. $N_{L,ph}\cdot KE_{L,ph}>\varepsilon_{Cr}$, does not occur being preceded in time by $N_{L,ph}\cdot KE_{L,ph}=\varepsilon_{Cr}$ and thus the laser emits photons that have equal momentum, are mono-energetic. and using a spectroscopic grid create a sharp spectral line.

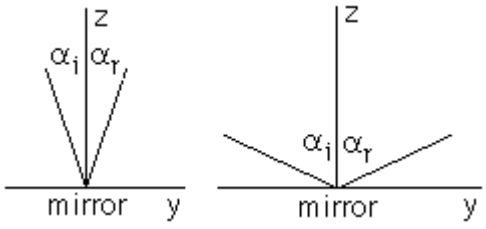
In reality 2 spectral lines are formed and consequently the Cr atoms are of two kinds with unequal photon creation energy $\varepsilon_{Cr,1}$ and $\varepsilon_{Cr,2}$ caused by Cr atoms with the same mass but unequal density distributions.

J. The binding energy of the photon is, $BE_{ph}=-\frac{m_{ph}^2 H}{r_{ph}}$ with momentum $m_{ph}c_{ph}=m_{ph}\cdot 10^n=1.1\cdot 10^{-23}gm\frac{cm}{sec}$ (see part D above). With $|BE_{ph}|+KE_{ph}=10ev=1.6\cdot 10^{-11}erg$ and $|BE_{ph}| >> KE_{ph}$; the $|BE_{ph}|$ becomes, $|BE_{ph}|\doteq 1.6\cdot 10^{-11}erg$. Solving $BE_{ph}=-\frac{m_{ph}^2 H}{r_{ph}}$ for r_{ph} yields: $r_{ph}=(0.76)\cdot 10^{-(2n+6)}cm$ and using e.g. $c_{ph}=10^{10}\frac{cm}{sec}$, r_{ph} becomes $r_{ph}=(7.6)\cdot 10^{-27}cm$. The radius of the laser photon is some $\sim 10^{-2}$ times smaller than the radius of a photon in the optical from a tungsten filament, see table 6.2, and uses $\sim 10^{-4}$ less energy to punch through e.g. an oxygen or nitrogen atom than a photon in the optical from a tungsten filament. This is the reason that laser light remains collated over long distances as it punches through atoms in the atmosphere with small loss in energy rather than reflecting or scattering from atmospheric atoms. See 6.26 and table 6.5.

10. Photon Reflection from a Mirror

The following A and B are well known to be observationally true.
A. The ∠incidence=∠reflection of a beam of light from a plane mirror.
B. A plane ⊥ to the plane of the mirror and going through the incoming narrow beam and a plane ⊥ to the plane of the mirror and going through the outgoing narrow beam are the same plane. Figure 6.8.
These laws may be observed using a thin film of Ag, Au, or Al plated on glass, or the surface of still water, or Hg, or polished obsidian rock etc.
Mirrors made of Ag and Au have been made since before Roman times presumably by melting and cooling the respective metal and then polishing with a wool?, cotton?, flax? cloth. It is a central hypothesis that any surface for which A and B are true has

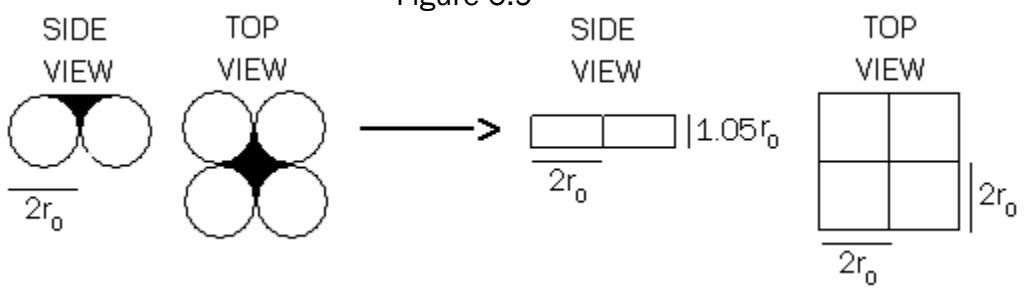
FIGURE 6.8



a reflecting surface on which the gaps between the atoms have been filled in with atomic material to form a planar surface.
In the case of mirrors whose reflecting surface is a transition metal that must be polished in order that the mirrors fulfill A and B above; The assumption made is that atoms of the polishing material striking the empty space between 4 atoms, fig. 6.9, attract and deform the upper surface of the metal atoms of the mirror into close enough proximity so that the attractive force between the deformed metal atoms forms a bond resulting in deformation of the metal atoms into bonded rectangular solids with a planar external surface preserving the volume of the metal atom. The dark space fig. 6.9 marks the empty space between atoms on the surface of the mirror before polishing.

In the case of material surfaces that naturally form mirrors such as still water, it is atmospheric pressure that cause a planar surface to form and it is attractive atomic forces between the atoms on the surface of the fluid that cause the surface atoms to form a rectangular solid filling in the space between the atoms. Refraction effects are discussed in sec. 11.
In the case of liquids such as Hg, it is attractive atomic forces on the surface of the fluid that cause the surface to form a convex shape and the attractive atomic forces cause the surface atoms to form a rectangular solid filling in the space between the atoms.
Assuming that the translational $KE_{ph} \lesssim |BE_{ph}|$, the photon will flatten on striking the planar mirror, decreasing the z component of the photon velocity to 0 $\frac{cm}{sec}$ and maintaining the y component (See fig. 6.8) and increasing Be_{ph} to $Be_{ph}+\frac{1}{2}m_{ph}(c_z)^2$. The photon will rebound from its' contact point and propel itself with final speed c_o and with its' initial binding energy BE_{ph}, preserving both energy and momentum and satisfying A and B above.

Figure 6.9

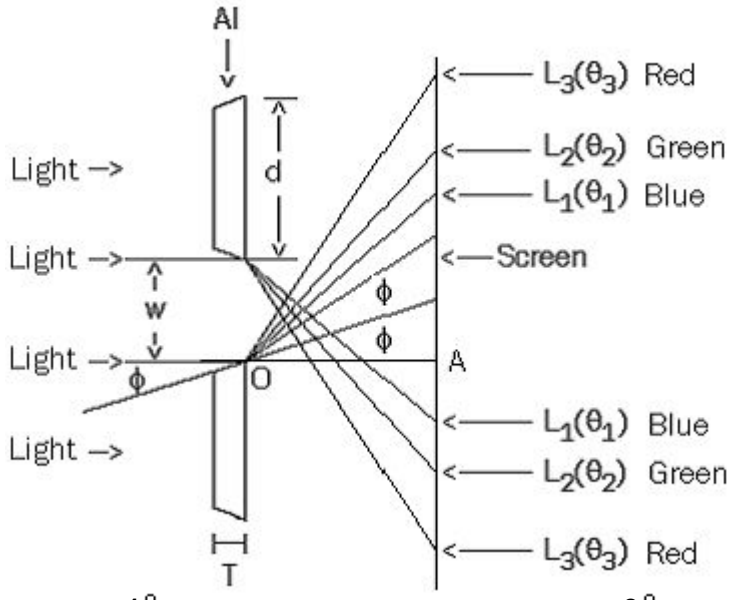


11. Photon Interaction with a Spectral Grating

In order to measure the wave length of light, one uses a spectral grating i.e. a smooth piece of plain glass thinly coated with Al upon which parallel lines a distance d apart are scratched with a diamond tipped needle using a ruling engine. The beveled diamond tipped needle scratches a line through the Al coating with azimuthal angle φ as in figure 6.10.

Assuming light is a self-interfering wave, one can derive Bragg's Law: $\lambda=d\sin\theta$ (First order spectrum for a transmission grating) where λ is the wavelength, d as above and θ is the angle through which light is diffracted. If one now makes a second grating with parallel lines a distance D apart using the same diamond tipped needle as above and shines the same monochromatic light source on both gratings, and assuming Bragg's law is correct: $\lambda=d\sin\theta=D\sin\theta_1$ where angle $\theta\neq\theta_1$. However experimentally $\theta=\theta_1$ and therefore Bragg's Law is experimentally false. This proves that e.m. radiation is not a wave and that the most important equation of quantum

FIGURE 6.10



$d\approx10^4\,\text{Å}$, w<<d (Not shown to scale), $T\approx10^3\,\text{Å}$

mechanics $E=h\nu$, is physically false and does not represent physical reality. The view advanced here is that electromagnetic radiation consists of solid mass photons and that individual photons have no frequency or wavelength. Individual photons are small angle scattered through discrete angles θ_f see fig. 6.10 where $\theta_1=\angle L_1OA$, $\theta_2=\angle L_2OA$, $\theta_3=\angle L_3OA$ as discussed below.

As regards photon small angle scattering, fig. 6.10 and 6.11. It is hypothesized that the coefficient of friction between mirror and photon for given φ, is sufficiently large so that:

1. After contact with the mirror, the photon begins to spin with rotation axis parallel to the x axis and with rotational energy $\frac{1}{2}I_o\omega^2$ and $I_o=\frac{2}{5}m_{ph}$.

2. With incident velocity $\underset{\sim}{c}_o=c_y\hat{y}+c_z\hat{z}$, the photon translational KE is:

$KE=\frac{1}{2}m_{ph}\{(c_y)^2+(c_z)^2\}=\frac{1}{2}m_{ph}(c_{y,s})^2+\frac{1}{2}I_o\omega^2+E_{fr}+\frac{1}{2}m_{ph}(c_z)^2$, and where $E_{fr}=E_{fr,gr}+E_{fr,ph}$. E_{fr} is the energy lost as heat to the Al grate and photon due to friction: $E_{fr,gr}$ to the grate and $E_{fr,ph}$ to the photon. $E_{fr,ph}$ is made manifest as vibrational energy around the center of mass of the photon.

3. With $\tan\varphi=\frac{c_z}{c_y}$ and $\alpha\equiv\frac{I_o\omega^2}{m_{ph}c_y^2}+2\frac{E_{fr}}{m_{ph}c_y^2}$ and $\tan\phi_s=\frac{c_z}{c_{y,s}}$, $\tan\phi_s$ becomes

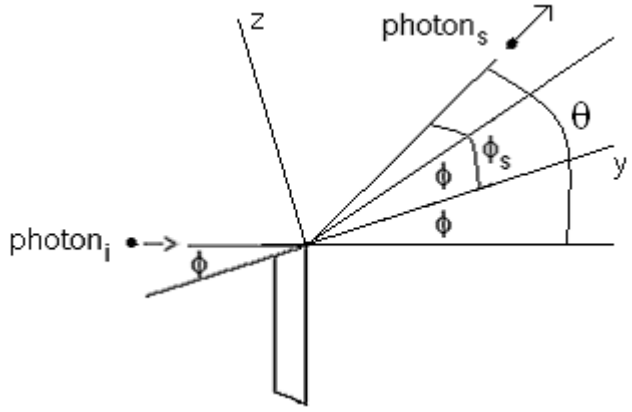
$\tan\phi_s=\frac{c_z}{c_y}\frac{c_y}{c_{y,s}}=\{[1-\alpha]^{-\frac{1}{2}}\}\tan\varphi$ and $\phi_s=\tan^{-1}\{\{[1-\alpha]^{-\frac{1}{2}}\}\tan\varphi\}$ i.e. $\varphi\le\phi_s\le\frac{\pi}{2}$ and $\phi_s=\theta-\varphi$

4. Using 3, $\alpha=1-(\frac{\tan\phi}{\tan(\theta-\phi)})^2$ $c_{y,s}=[1-\alpha]^{\frac{1}{2}}c_y$.

5. The photon leaves the mirror preserving B above.

Consider the following derivation of α. As the photon collides with the grating it experiences an acceleration and force in the z direction, see fig. 6.11, where the average acceleration in the $\hat{z}$ direction is: $\bar{a}_z=\frac{\bar{F}_z}{m_{ph}}=2\frac{c_z}{\Delta t}$ and where Δt is the contact time between the photon and grating. Due to frictional forces, the photon experiences a deceleration and force in the $-\hat{y}$ direction where the average deceleration and force

FIGURE 6.11



in the $-\hat{y}$ direction is: $\bar{a}_y=\frac{\bar{F}_y}{m_{ph}}=\frac{\Delta c_y}{\Delta t}=\frac{c_{y,s}-c_y}{\Delta t}$ and assuming $\bar{F}_y=-R\cdot\bar{F}_z$, $\bar{a}_y$ becomes:

$\bar{a}_y=\frac{\bar{F}_y}{m_{ph}}=\frac{c_{y,s}-c_y}{\Delta t}=-R\cdot\frac{\bar{F}_z}{m_{ph}}=-2R\cdot\frac{c_z}{\Delta t}$ and $c_{y,s}-c_y=-2R\cdot c_z$.

Using 3 and 4 above, $\frac{c_{y,s}}{c_y}=[1-\alpha]^{\frac{1}{2}}=\frac{\tan\phi}{\tan(\theta-\phi)}=1-2R\cdot\frac{c_z}{c_y}=1-2R\cdot\tan\varphi$ and solving for R and compiling results:

6.35 $\alpha=1-(\frac{\tan\phi}{\tan(\theta-\phi)})^2$ and $R=\frac{1}{2\tan\phi}(1-\frac{\tan\phi}{\tan(\theta-\phi)})$ $c_{y,s}=c_o\frac{\sin\phi}{\tan(\theta-\phi)}$ $\phi_s=\theta-\varphi\geq\varphi$

As regards the formation of continuous and line spectra by the scattering of solid mass photons from a spectroscopic grating as in figure 6.10 and 6.11.
Consider the four lines in the optical of the Balmer Series. Observationally:
$\theta_{R_s}>\theta_{G_s}>\theta_{B_s}>\theta_{V_s}>0$ where R, G, B,V stand respectively for red, green, blue, violet.

By assumption:

6. $|\underset{\sim}{p}_{ph_R}|<|\underset{\sim}{p}_{ph_G}|<|\underset{\sim}{p}_{ph_B}|<|\underset{\sim}{p}_{ph_V}|$ where e.g. $|\underset{\sim}{p}_{ph_R}|=m_Rc_{o,R}$ is the absolute value of the incident linear momentum. m_R is the mass of the red photon and $c_{o,R}$ is the incident speed of the red photon. It is not assumed that $m_R=m_G$ etc. and it is not assumed that $c_{o,R}=c_{o,G}$ etc.
7. $|\underset{\sim}{p}_{ph_{S,R}}|<|\underset{\sim}{p}_{ph_{S,G}}|<|\underset{\sim}{p}_{ph_{S,B}}|<|\underset{\sim}{p}_{ph_{S,V}}|$ where e.g. $|\underset{\sim}{p}_{ph_{S,R}}|=m_Rc_{S,R}$ is the absolute value of the scattered linear momentum. $c_{S,R}$ is the scattered speed of the red photon and it is not assumed that $c_{o,R}=c_{S,R}$ and it is not assumed that $c_{S,R}=c_{S,G}$ etc.

Observationally the red line of the Balmer series have been measured for $\theta_3=\angle L_3OA\approx20^o$ and the violet line for $\theta_1=\angle L_1OA\approx10^o$ (Figure 6.10). With $\theta_3=20^o$ and $\phi\leq\frac{1}{2}\theta$ and incoming speed $c_{o,R}$, and using 6.35, the red line has by direct computation:
$c_{S,R}=(c_{y,s,R}^2+c_{z,R}^2)^{\frac{1}{2}}=([\frac{\sin\phi}{\tan(20-\phi)}]^2+[\sin\phi]^2)^{\frac{1}{2}}c_{o,R}=c_{o,R}\cdot\sin\phi(1+[\frac{1}{\tan(20-\phi)}]^2)^{\frac{1}{2}}$, with a similar expression for $c_{S,V}$. Table 6.10 lists computed values of $c_{S,R}$ and $c_{S,V}$ as a function of ϕ. Angles in degrees.
The physically correct value of ϕ resulting in $\theta_3=20^o$ and $\theta_1=10^o$ is not known a-priori and for the Balmer Series it is not known if green in equals green scattered and if violet in equals violet scattered etc. The original hypothesis was that in order for color in to equal color scattered, momentum in must equal momentum scattered. In general using table 6.8, linear momentum in does not equal linear momentum

TABLE 6.10

ϕ	θ_3	$\frac{c_{S,R}}{c_{o,R}}$	ϕ	θ_1	$\frac{c_{S,V}}{c_{o,V}}$
0.1	20	$5.1\cdot10^{-3}$	0.1	10	$1.0\cdot10^{-2}$
1	20	$5.4\cdot10^{-2}$	1	10	$1.1\cdot10^{-1}$
5	20	$2.6\cdot10^{-1}$	5	10	1.0

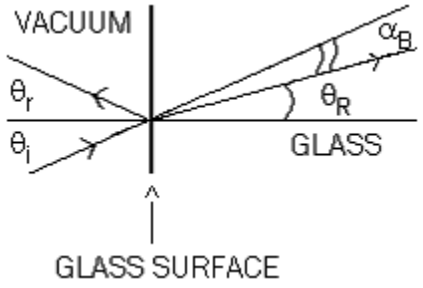
scattered. Using $\phi \leq \frac{1}{2}\theta \leq \frac{1}{2}\theta_1 \leq \frac{1}{2}\theta_3$ yields $\phi \leq 5^o$. However, linear momentum in does not equal linear momentum out for $\theta_3 = 20^o$ but observationally, red in $\approx$ red scattered. The resulting generalized hypothesis is that a spinning, radially oscillating photon has an optically, physiologically effective momentum p_{eff} such that $m_R c_{o,R} \doteq p_{eff,R}$ and $m_V c_{o,V} \doteq p_{eff,V}$ etc. where using 2 above: $m_{ph} c_o \doteq p_{eff} = m_{ph}\left\{c_{y,s}^2 + \frac{I_o\omega^2 + 2E_{fr,ph}}{m_{ph}} + c_z^2\right\}^{\frac{1}{2}}$ with $E_{fr} = E_{fr,gr} + E_{fr,ph}$ and $\frac{1}{2}I_o\omega^2 + E_{fr,ph} > E_{fr,gr}$. Applying the general expression to R and V yields, $m_R c_{o,R} \doteq p_{eff,R} = m_R\left\{c_{y,s,R}^2 + \left[\frac{I_o\omega^2 + 2E_{fr,ph}}{m_{ph}}\right]_R + c_{z,R}^2\right\}^{\frac{1}{2}}$ and $m_V c_{o,V} \doteq p_{eff,V} = m_V\left\{c_{y,s,V}^2 + \left[\frac{I_o\omega^2 + 2E_{fr,ph}}{m_{ph}}\right]_V + c_{z,V}^2\right\}^{\frac{1}{2}}$. The resulting scattered light will be red shifted but how much it is red shifted must be determined by a color sensitive human eye.

2nd order spectra are generated when there exist a ϕ_1 and a ϕ_2 ($\phi_1 \neq \phi_2$) , such that e.g. $\frac{2}{3}$ of the slots have ϕ_1, and $\frac{1}{3}$ of the slots have ϕ_2. The 1st order spectrum is generated from the slots with ϕ_1 and the 2nd order spectrum is generated from the slots with ϕ_2.
3rd order spectra ...

12. Photon Interaction with a Glass Plate and with a Glass Prism

Light incident on a flat glass plate, figure 6.12, undergoes both reflection and refraction. How is it possible that the Si and O atoms of the glass are able to reflect $\approx$ 4% and transmit $\approx$ 96% of the incident optical photons for $\theta_i = 0^o$ and reflect 99+% and refract <<1% of the incident optical photons for grazing incidence $89^o \lesssim \theta_i < 90^o$. θ_i=angle of incidence, θ_r=angle of reflection, θ_R=angle of refraction and α_B=bent angle. Using Snell's law, values of α_B are computed for a vacuum-zinc crown glass interface as a function of θ_i and listed in table 6.11. α_{B_R} is the computed bent angle for red

FIGURE 6.12



light with a refraction index n_R=1.511 and α_{B_V} is the computed bent angle for violet light with a refraction index n_V=1.528.

TABLE 6.11

θ_i	α_{B_R}	θ_{R_R}	α_{B_V}	θ_{R_V}
1^o	0.338^o	0.662^o	0.346^o	0.654^o
10^o	3.40^o	6.60^o	3.47^o	6.53^o
30^o	10.7^o	19.3^o	10.9^o	19.1^o
60^o	25.0^o	35.0^o	25.5^o	34.5^o
90^o	48.6^o	41.4^o	49.1^o	40.9^o

Define $I(\theta_i,P_{ph})_i$ as the incident radiation intensity at angle θ_i of a mono-energetic beam of photons with momentum $(P_{ph})_i$. $I(\theta_i,P_{ph})_i = (\frac{\#ph}{sec})_i \cdot (P_{ph})_i$ where $(\frac{\#ph}{sec})_i$ is the number of incoming photons per sec per cm^2 incident on the vacuum glass interface at angle θ_i with momentum $(P_{ph})_i$. Define $I(\theta_r,P_{ph},n)_r$ as the radiation intensity reflected from a medium with index of refraction n at angle $\theta_r=\theta_i$. Given $(\frac{\#ph}{sec})_i$ and $(P_{ph})_i$: $I(\theta_r,P_{ph},n)_r = (\frac{\#ph}{sec})_r \cdot (P_{ph})_r$ where $(\frac{\#ph}{sec})_r$ is the number of photons per sec reflected from the given atom on the vacuum glass interface at angle $\theta_r=\theta_i$ with momentum $(P_{ph})_i$. Experimentally, if $\theta_{i_1}<\theta_{i_2}$ and $I(\theta_{i_1},P_{ph_1})_i=I(\theta_{i_2},P_{ph_2})_i$ and $(P_{ph_1})_i=(P_{ph_2})_i$ then observationally $I(\theta_{r_1},P_{ph_1},n)_r < I(\theta_{r_2},P_{ph_2},n)_r$.

Also experimentally: $\frac{I(0^0,P_{ph},n)_r}{I(0^0,P_{ph})_i} = \frac{(n-1)^2}{(n+1)^2}$. For red light with refractive index n=1.511, $\frac{I(0^0,P_{ph_R},1.511)_r}{I(0^0,P_{ph_R})_i}$ =4.1% and $\frac{I((90^0)^-,P_{ph_R},1.511)_r}{I((90^0)^-,P_{ph_R})_i}$ =99+%. For violet light with refractive index n=1.528, $\frac{I(0^0,P_{ph_V},1.528)_r}{I(0^0,P_{ph_V})_i}$ =4.4% and $\frac{I((90^0)^-,P_{ph_V},1.528)_r}{I((90^0)^-,P_{ph_V})_i}$ =99+%.

This means that at normal incidence 4.1% of the incident red photons and 4.4% of the incident violet photons are reflected and 95.9% of the red photons and 95.6% of the violet photons are transmitted and at grazing incidence 99+%of the red and violet photons are reflected.

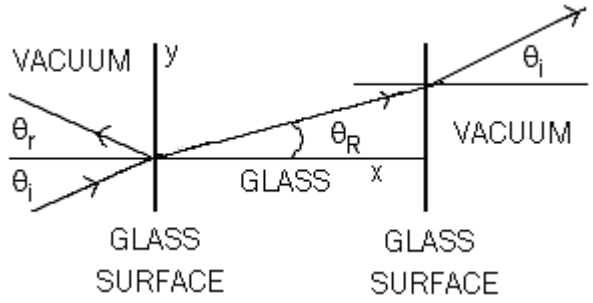
Observationally refraction is seen to be a surface phenomena occurring at density interfaces and not in the interior of constant density mediums. As in the creation of mirrors, it is assumed that in the creation of plate glass, (e.g. float glass, polished sheet glass, etc.), the atoms on the surface of the glass are attracted to one another

(With the aid of atmospheric molecules) filling in the gaps between the atoms on the surface forming a plane like that of fig. 6.8 and 6.9.
Let the speed of light in vacuum be c_o and the speed of light in the glass c_G with $\underset{\sim}{c}_o=c_o(\cos\theta_i\hat{x}+\sin\theta_i\hat{y})$ and $\underset{\sim}{c}_G=c_G(\cos\theta_R\hat{x}+\sin\theta_R\hat{y})$. Figure 6.13.
Assuming that $c_G=\frac{c_o}{n}$ the translational kinetic energy lost by a photon on entering the glass is:

$$\Delta KE_{ph}=\int \underset{\sim}{f}\cdot d\underset{\sim}{s}=m_{ph}\int \frac{d\underset{\sim}{c}}{dt}\cdot d\underset{\sim}{s}=m_{ph}\int d\underset{\sim}{c}\cdot\frac{d\underset{\sim}{s}}{dt}=m_{ph}\int \underset{\sim}{c}\cdot d\underset{\sim}{c}=\frac{1}{2}m_{ph}c^2\Big|_{c_o}^{\frac{c_o}{n}}=-\frac{1}{2}\left(\frac{n^2-1}{n^2}\right)m_{ph}(c_o)^2$$

independent of θ_i or θ_R.
On entering the glass, the photon has a change in speed of $c_o(\frac{1}{n}\cos\theta_R-\cos\theta_i)$ in the $\hat{x}$ direction and has a change speed of $c_o(\frac{1}{n}\sin\theta_R-\sin\theta_i)$ in the $\hat{y}$ direction. On exiting thin enough glass, the photon has a change in speed of $-c_o(\frac{1}{n}\cos\theta_R-\cos\theta_i)$ in the $\hat{x}$ direction and has a change speed of $-c_o(\frac{1}{n}\sin\theta_R-\sin\theta_i)$ in the $\hat{y}$ direction. How is this possible?

FIGURE 6.13



It is hypothesized that on entering the glass, the photon is compressed and loses kinetic energy ΔKE_{ph} and gains $\Delta C_1=-\Delta KE_{ph}$ internal energy and that on exiting the glass, the photon gains kinetic energy $-\Delta KE_{ph}$ and loses $-\Delta C_1=\Delta KE_{ph}$ internal energy. The total impulse $\underset{\sim}{I}$ experienced by the photon is:

$$\underset{\sim}{I}\equiv\int \underset{\sim}{f}\cdot dt=m_{ph}\int\frac{d\underset{\sim}{c}}{dt}\cdot dt=m_{ph}\int d\underset{\sim}{c}=m_{ph}\underset{\sim}{c}\Big|_{\underset{\sim}{c}_o}^{\underset{\sim}{c}_G}=-\{(\cos\theta_i-\frac{1}{n}\cos\theta_R)\hat{x}+(\sin\theta_i-\frac{1}{n}\sin\theta_R)\hat{y}\}m_{ph}c_o$$

With $I_x=-(\cos\theta_i-\frac{1}{n}\cos\theta_R)m_{ph}c_o$, where $I_x\le 0$ for $0\le\theta_i\le\sin^{-1}\left\{\frac{n}{(n^2+1)^{\frac{1}{2}}}\right\}$ and $I_x>0$ for $\sin^{-1}\left\{\frac{n}{(n^2+1)^{\frac{1}{2}}}\right\}<\theta_i\le\frac{\pi}{2}$. Also $I_y=-(\sin\theta_i-\frac{1}{n}\sin\theta_R)m_{ph}c_o<0$ for $0\le\theta_i\le\frac{\pi}{2}$

The origin of the force is hypothesized to be, the point to point density difference along the flight path of the photon.

How is it possible that monochromatic optical photons for $0 \le \theta_i \le \frac{\pi}{2}$, some reflect and others refract? See figure 6.13 where the REFLECTION COEFFICIENT $\equiv \frac{I(\theta_i, P_{ph}, n)_r}{I(\theta_i, P_{ph})_i}$.

A. In order to explain the reflection coefficient, it is hypothesized that all monochromatic optical photons have a distribution of radii, n such that $dn = n(r_{o,i})dr_{o,i}$ with $r_{o,m} \le r_{o,i} \le r_{o,M}$ and $N = \int_{r_{o,m}}^{r_{o,M}} dn = \int_{r_{o,m}}^{r_{o,M}} n(r_{o,i})dr_{o,i}$ where N is the total number of photons in a given sample.

For $\theta_i = 0^o$, 95.1% of the red photons have a radius small enough and x component (fig 6.13) of momentum large enough to penetrate the glass and 4.6% of the photons have a radius too large and x component of momentum too small to penetrate the glass and consequently reflect.

For $\theta_i = 90^o$, less than 1% of the red photons have a radius small enough and x component of momentum large enough to penetrate the glass and 99+% of the photons have a radius too large and x component of momentum too small to penetrate the glass and consequently reflect.

Similar statements hold for arbitrary θ_i and optical color.

For future reference as regards white light striking an isosceles glass prism: On exiting the prism, the photon paths are bent away from the normal. Figure 6.15

With $n_R = 1.511$ and $n_V = 1.528$ as used in table 6.8, and $\theta_i = 20^o$, $\gamma = 70^o$, then as measured from the horizontal, $\alpha_R = 23.2^o$ and $\alpha_V = 24.0^o$.

FIGURE 6.14

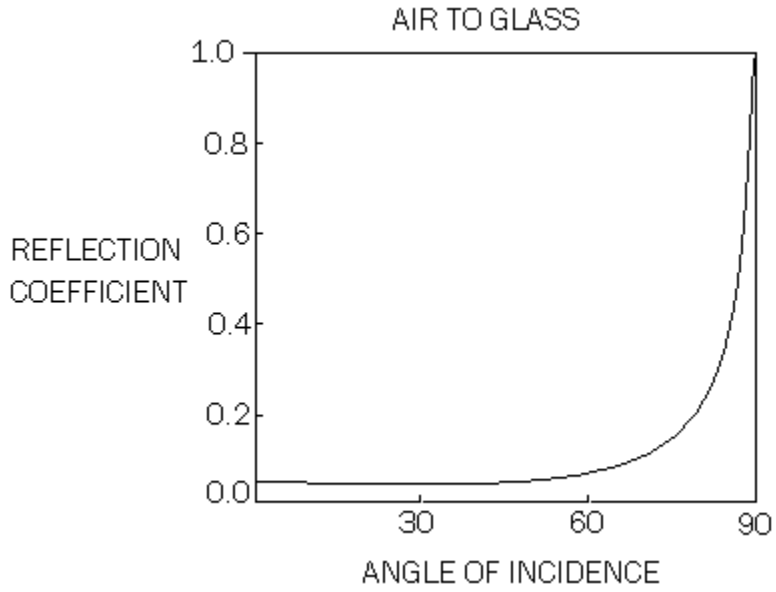
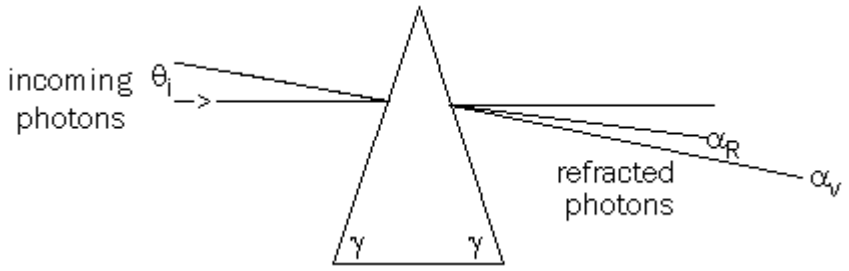


FIGURE 6.15



13. Black Body Radiation

A black body is defined to be any solid for which all incident photons are adsorbed and none reflected. The photons emitted by a black body at temperature T are created by atomic collisions of the atoms of the black body as derived in chapter 6, section 5. A kaolin clay block heated to temperature T such that it emits photons in the visible is experimentally taken to be a black body.
Consider a hollow cavity completely contained within the clay block. In the following the energy density $\overline{\chi}$ $(\frac{ergs}{cm^3})$ of the radiation in the cavity will be derived in two ways.
(i) Assume the radiation is electromagnetic.
(ii) Assume the radiation is composed of small mass photons.

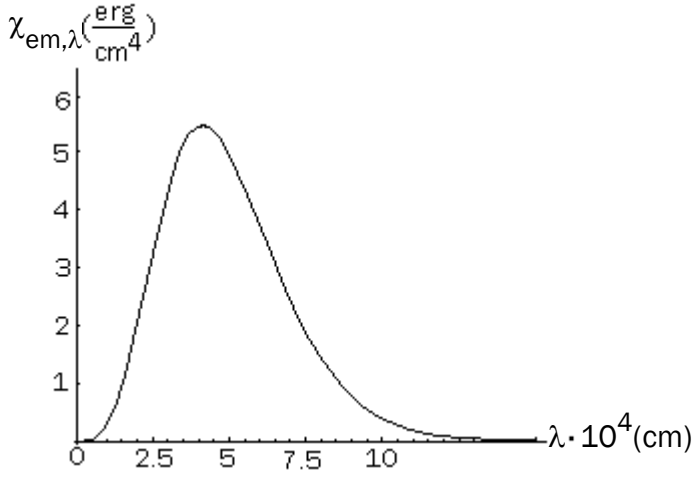
A small hole of radius r_H is drilled into the side of the clay block and into the cavity. To make up for photon energy losses through the hole, additional power must be provided to the clay block to maintain it at temperature T.
Assuming the radiation emitted by the clay block is electromagnetic radiation, the energy density χ_{em} $(\frac{erg}{cm^3})$, and the energy density per unit wave length $\chi_{em,\lambda}$ $(\frac{erg}{cm^4})$, as derived by Planck are:

6.36 a. $\chi_{em} \doteq 48\pi \frac{(KT)^4}{(hc_0)^3}$ $(\frac{erg}{cm^3})$ for $\lambda T \lesssim 0.28$ (See sec. 15, appendix 6C)

b. $\chi_{em,\lambda} = 8\pi \frac{hc_0}{\lambda^5} ((\exp \frac{hc_0}{\lambda KT}) - 1)^{-1} (\frac{erg}{cm^4})$

A plot of $\chi_{em,\lambda} = 8\pi \frac{hc_0}{\lambda^5} ((\exp \frac{hc_0}{\lambda KT}) - 1)^{-1}$ as a function of λ is given in figure 6.16 for $T = 800^oK$.

FIGURE 6.16



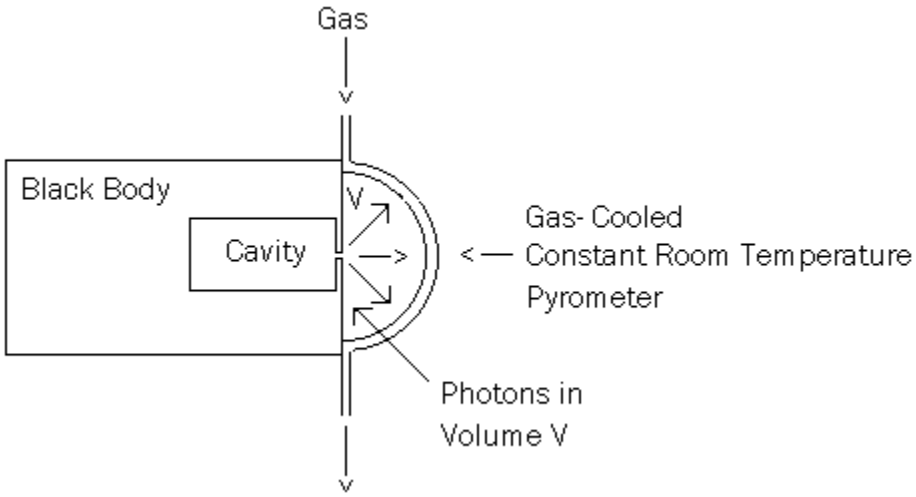
Electromagnetic Model for Radiation, T=800^{o}K

The electromagnetic power emitted through the hole $(\frac{1}{\pi r_H^2})P_{em,H}=(0.25)c_o\chi_{em}$ and the electromagnetic power emitted per unit wavelength through the hole $(\frac{1}{\pi r_H^2})P_{\lambda,em,H}=(0.25)c_o\chi_\lambda$ is:

6.37 a. $(\frac{1}{\pi r_H^2})P_{em,H}=12\pi c_o\frac{(KT)^4}{(hc_o)^3}(\frac{erg}{cm^2sec})=\sigma T^4$, $\sigma= 5.6\cdot 10^{-5}(\frac{erg}{cm^2sec^oK^4})$

b. $(\frac{1}{\pi r_H^2})P_{\lambda,em,H}=2\pi\frac{hc_o^2}{\lambda^5}((\exp\frac{hc_o}{\lambda KT})-1)^{-1}(\frac{erg}{cm^3sec})$

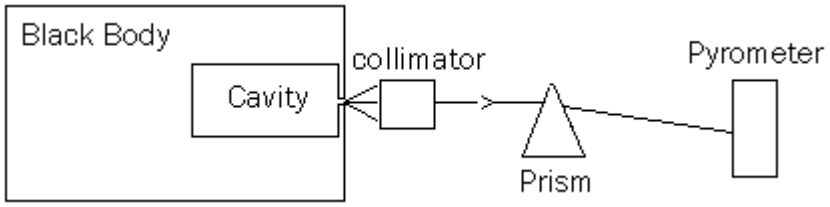
FIGURE 6.17



$(\frac{1}{\pi r_H^2})P_{em,H}$ is determined using a pyrometer as diagramed in figure 6.17. T should be measured by introducing a suitable gas, (Rn, UFl_6), into the cavity and measuring its v_{rms} as it exits the hole. T is determined using $\frac{1}{2}m_{gas}v_{rms}^2=2KT$ as derived below.

$(\frac{1}{\pi r_H^2})P_{\lambda,em,H}$ is measured using the experimental set up diagrammed in figure 6.18.

FIGURE 6.18



In the derivation of χ_{em}, $\chi_{em,\lambda}$, $(\frac{1}{\pi r_H^2})P_{em,H}$ and $(\frac{1}{\pi r_H^2})P_{\lambda,em,H}$ it is assumed that $\varepsilon_{ph}=h\nu=\frac{hc_0}{\lambda}$. The wave length of light is measured by using Bragg's Law, $\lambda=d\sin\theta$, and a spectroscopic grating. Assuming light is a self-interfering wave, one can derive Bragg's Law: $\lambda=d\sin\theta$ (First order spectrum for a transmission grating) where λ is the wavelength, d and θ as in sec.10 where θ is the angle through which light is diffracted. If one now makes a second grating with parallel lines a distance D ($D\neq d$) apart using the same diamond tipped needle as above and shines the same monochromatic light source on both gratings, and assuming Bragg's law is correct: $\lambda=d\sin\theta=D\sin\theta_1$ where angle $\theta\neq\theta_1$. However experimentally $\theta=\theta_1$ and therefore Bragg's Law is experimentally false. This proves that e.m. radiation is not a wave. The view advanced here is that electromagnetic radiation consists of solid mass photons and that individual photons have no frequency or wavelength. Individual photons are small angle scattered through discrete angles θ_f see fig. 6.10 where $\theta_1=\angle L_1OA$, $\theta_2=\angle L_2OA$, $\theta_3=\angle L_3OA$ as discussed in sec.10.

Experimentally for a given color of light, θ is a function of φ (Figure 6.10) and by experimentally varying φ holding d fixed, one varies computed λ using Bragg's law. Also holding φ fixed and varying d for a given color of light, θ remains fixed. Consequently by judicious choice of φ and d and measuring θ, one can assign multiple wave lengths or frequencies to a given color of light. Consequently the assignment of ε_{ph} to a particular optical color, e.g. red, is erroneous and derived χ_{em}, $\chi_{em,\lambda}$, $(\frac{1}{\pi r_H^2})P_{em,H}$ and $(\frac{1}{\pi r_H^2})P_{\lambda,em,H}$ are physically false.

How then is it possible that experimentally determined $(\frac{1}{\pi r_H^2})P_{\lambda,em,H}$ equals

experimentally determined $2\pi\frac{hc_o^2}{\lambda^5}((\exp\frac{hc_o}{\lambda KT})-1)^{-1}(\frac{erg}{cm^3 sec})$, (Ref. 6.7) where $(\frac{1}{\pi r_H^2})P_{\lambda,em,H}=\frac{1}{4}c_o\chi_{em,\lambda}$. It is hypothesized that by controlling the air pressure inside the experimental chamber at temperature T one can vary $(\frac{1}{\pi r_H^2})P_{\lambda,em,H}$ so as to make $(\frac{1}{\pi r_H^2})P_{\lambda,em,H}=2\pi\frac{hc_o^2}{\lambda^5}((\exp\frac{hc_o}{\lambda KT})-1)^{-1}(\frac{erg}{cm^3 sec})$.

Assuming the radiation is composed of small mass photons, it is further assumed that the photons have a Maxwell-Boltzmann distribution of energies, and as will be shown: the time averaged energy density of small mass photons in the cavity is $\overline{\chi}_{sm}=\frac{3}{2}\overline{n}_{ph}KT$, where $\overline{n}_{ph}$ is the time averaged photon number density.

The Maxwell-Boltzmann distribution of energies is $d\overline{n}_w=\frac{2}{\sqrt{\pi}}(KT)^{-\frac{3}{2}}\overline{n}_{ph}w^{\frac{1}{2}}\exp(-\frac{w}{KT})dw$, and the total energy of those photons with energy w, per unit energy per cm^3, $\overline{\chi}_{w,sm}$, is: $\overline{\chi}_{w,sm}\equiv w\frac{d\overline{n}_w}{dw}=\frac{2}{\sqrt{\pi}}\overline{n}_{ph}(\frac{w}{KT})^{\frac{3}{2}}\exp(-\frac{w}{KT})$ and by direct computation,

$$\overline{\chi}_{sm}=\int_0^\infty w\,d\overline{n}_w=\frac{2}{\sqrt{\pi}}\overline{n}_{ph}\int_0^\infty(\frac{w}{KT})^{\frac{3}{2}}\exp(-\frac{w}{KT})\,dw=\frac{3}{2}\overline{n}_{ph}KT \text{ where } w=\frac{1}{2}m_{ph}c_{ph}^2.$$

6.38 a. $\overline{\chi}_{sm}=\frac{3}{2}\overline{n}_{ph}KT\,(\frac{erg}{cm^3})$

b. $\overline{\chi}_{w,sm}=\frac{2}{\sqrt{\pi}}\overline{n}_{ph}(\frac{w}{KT})^{\frac{3}{2}}\exp(-\frac{w}{KT})\,(\frac{1}{cm^3})$

The number of photons per second, (#/sec), going through the hole with speeds between c and c+dc is: $dN_{c,sm,H}=(\pi r_H^2)(\frac{1}{4}cd\overline{n}_c)(\#/sec)$ where $d\overline{n}_c$ is the Maxwellian distribution of photon speeds in the cavity. The rms speed of those photons going through the hole is $c_{rms,sm,H}^2=(\int_0^\infty c^2dN_{c,sm,H})/(\int_0^\infty dN_{c,sm,H})=(\frac{1}{4}\int_0^\infty c^3d\overline{n}_c)/(\frac{1}{4}\int_0^\infty cd\overline{n}_c)$

where $d\overline{n}_c=\frac{4}{\sqrt{\pi}}\overline{n}_{ph}(\frac{2KT}{m_{ph}})^{-\frac{3}{2}}c^2\exp(-\frac{m_{ph}c^2}{2KT})dc=\frac{2}{\sqrt{\pi}}\overline{n}_{ph}(KT)^{-\frac{3}{2}}w^{\frac{1}{2}}\exp(-\frac{w}{KT})dw=d\overline{n}_w$.

By direct computation: $\frac{1}{2}m_{ph}c_{rms,sm,H}^2=2KT$.

The power due to all photons going through the hole is: $P_{sm,H}=2KT\int_0^\infty dN_{c,sm,H}=2KT\int_0^\infty dN_{W,sm,H}=$

$$2KT(\pi r_H^2)\frac{1}{4}\int_0^{\infty}\left(\frac{2w}{m_{ph}}\right)^{\frac{1}{2}}d\bar{n}_w=\left(\frac{2\pi}{m_{ph}KT}\right)^{\frac{1}{2}}\cdot\bar{n}_{ph}r_H^2\int_0^{\infty}w\exp\left(-\frac{w}{KT}\right)dw=\left(\frac{2\pi KT}{m_{ph}}\right)^{\frac{1}{2}}\cdot\bar{n}_{ph}r_H^2\,KT\ (\text{erg/sec})$$

The power due to all photons going through the hole with energy W per unit energy, $P_{w,sm,H}$, is: $P_{w,sm,H}\equiv w\frac{dN}{dw}w,sm,H=w(\pi r_H^2)\frac{1}{4}\left(\frac{2w}{m_{ph}}\right)^{\frac{1}{2}}\frac{d\bar{n}_w}{dw}$ where

$\frac{d\bar{n}_w}{dw}=\frac{2}{\sqrt{\pi}}\bar{n}_{ph}(KT)^{-\frac{3}{2}}w^{\frac{1}{2}}\exp\left(-\frac{w}{KT}\right)$. By direct computation:

6.39 a. $\left(\frac{1}{\pi r_H^2}\right)P_{sm,H}=\left(\frac{2KT}{\pi m_{ph}}\right)^{\frac{1}{2}}\cdot\bar{n}_{ph}KT\left(\frac{erg}{sec\,cm^2}\right)$

b. $\left(\frac{1}{\pi r_H^2}\right)P_{w,sm,H}=\left(\frac{KT}{2\pi m_{ph}}\right)^{\frac{1}{2}}\cdot\bar{n}_{ph}\left(\frac{w}{KT}\right)^2\exp\left(-\frac{w}{KT}\right)\left(\frac{1}{sec\,cm^2}\right)$

$\bar{n}_{ph}$ and T in 6.38 and 6.39 are the same.

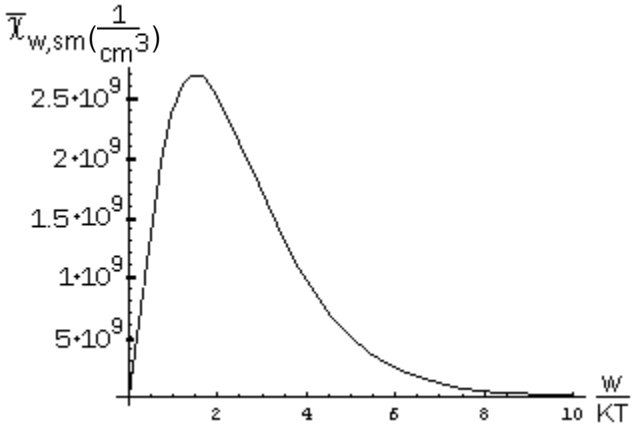
A plot of $\bar{\chi}_{w,sm}\left(\frac{1}{cm^3}\right)$ as a function of w, is given in figure 6.19,

6.39a. may be written for atoms with mass m_{At} and number density of air molecules in the cavity $\bar{n}_{ar}$.

6.39 c. $\left(\frac{1}{\pi r_H^2}\right)P_{At,H}=\left(\frac{2KT}{\pi m_{At}}\right)^{\frac{1}{2}}\cdot\bar{n}_{ar}KT\left(\frac{erg}{sec\,cm^2}\right)$

The ratio $\frac{P_{sm,H}}{P_{At,H}}$ is: $\frac{P_{sm,H}}{P_{At,H}}=\left(\frac{m_{At}}{m_{ph}}\right)^{\frac{1}{2}}\cdot\frac{\bar{n}_{ph}}{\bar{n}_{ar}}$. The cavity in the black body contains air molecules as well as photons. Let $p_{ar}=10^n\left(\frac{dy}{cm^2}\right)$ be the partial pressure due to air

FIGURE 6.19



Small Mass Photon Model for Radiation, T=800°K

molecules in the cavity where $10^6(\frac{dy}{cm^2})$ is standard atmospheric pressure. Using the ideal gas law, $\bar{n}_{ar}=\frac{p_{ar}}{KT}=9.1\cdot 10^{12+n}(\frac{Atoms}{cm^3})$.

An upper bound for $\bar{n}_{ph}$ is achieved by assuming the cavity walls are emitting power equivalent to the solar constant where $S.C.=1.4\cdot 10^6(\frac{erg}{cm^2 sec})$. At equilibrium, the number of photons σ_{ph} emitted by the cavity walls per cm^2 per sec, equals the number of photons striking the cavity walls per cm^2 per sec. i.e. $\sigma_{ph}=\frac{1}{4}\bar{n}_{ph}\bar{v}_{ph}$. At 800^oK the translational Kinetic Energy of a photon is $1.6\cdot 10^{-13}$ erg and $\sigma_{ph}=\frac{1.4\cdot 10^6}{1.6\cdot 10^{-13}}=8.8\cdot 10^{18}$ and $\bar{n}_{ph}$ becomes: $\bar{n}_{ph}=4\frac{\sigma_{ph}}{\bar{v}_{ph}}\approx\frac{10^{19}}{10^{11}}=10^8$. $\frac{P_{sm,H}}{P_{At,H}}$ becomes: $\frac{P_{sm,H}}{P_{At,H}}=(\frac{m_{At}}{m_{ph}})^{\frac{1}{2}}\cdot\frac{\bar{n}_{ph}}{\bar{n}_{ar}}\approx(\frac{10^{-23}}{10^{-34}})^{\frac{1}{2}}(\frac{10^8}{10^{13+n}})\approx 10^{-n}$. The total measured emitted power through the hole $P_{T,H}$ is $P_{T,H}=P_{sm,H}+P_{At,H}$ and for $0<n\leq 6$, $P_{sm,H} < P_{At,H}$. Given experimentally determined $P_{T,H}$; $P_{At,H}$ cannot be ignored for $-1<n\leq 6$ when computing $P_{sm,H}=P_{T,H}-P_{At,H}$

14. Appendix 6A

Two terms are missing in the computation of the force F(dyn) necessary to accelerate a photon through an atom from V=0 to $V=3\cdot 10^{10}\frac{cm}{sec}$. These are:

a. The atomic field force $\underset{\sim}{F}_{at}=-m_{ph}\nabla\psi_W$ acting on the photon. By direct computation, $F_{at}=\frac{m_{ph}m_W H}{r_o}(\frac{h_o^{p+1}}{r_o^{p+2}})\approx 10^{-17}(\frac{h_o^{p+1}}{r_o^{p+2}})$. For $-1\leq p\leq 0$, $F_{at}\lesssim 10^{-17}(\frac{1}{r_o})\doteq 10^{-9}$dy and $F_{at}<<F$ where F is the F of table 6.4 and may be ignored. For $-3<p<-1$, F_{at} must be computed on a case by case basis as it is possible that $F_{at}>F$. p determines the density of the atom. $\rho(h_o)=\frac{(p+3)m_w}{4\pi r_o^3}(\frac{h_o}{r_o})^p$ with $0\leq r\leq r_o$.

b. The force necessary to push the atomic material in front of the photon from $h=h_o$ to $h=r_o$ out of the path of the moving photon. The average force F_{be} is given by $F_{be}=\frac{be}{r_o-h_o}$ where be is the binding energy of the cylinder with volume $v_{cyl}=\pi r_{ph}^2(r_o-h_o)$. be is calculated in sec. 7 and compiled in table 6.5. In general for $-2.5\lesssim p\leq 0$, $F_{be}<<F$ where F is the F of table 6.4 and may be ignored.

15. Appendix 6B

Using the fictitious atomic potential $\psi_f(r)=-\frac{m_{At}H}{r}$ valid for $0<r<\infty$, the fictitious potential energy of two identical solid mass atoms is $\Phi_f(r)=-\frac{m_{At}^2H}{r_1}$ where r_1 is the center of mass to center of mass distance between the 2 atoms. The fictitious specific heat C_{p_f} is: $C_{p_f}\doteq KE+PE_f=1.5K+3\cdot\frac{d\Phi}{dT}f=3\frac{d\Phi}{dr_1}f\frac{dr_1}{dT}=1.5K+3\frac{m_{At}^2H}{r_1^2}(2r_o)\alpha\,(T)$

$\alpha(T)$ has been computed and is given in chap.4, ref. 1. Using Pb as an example, $(2r_o)\alpha\,(300)=9.0\cdot10^{-13}\frac{erg}{K^o}$ and $3\cdot\frac{d\Phi}{dT}f=3\frac{m_{At}^2H}{r_1^2}(2r_o)\alpha\,(300)=3.3\cdot10^{-10}\frac{erg}{K^o}\doteq C_{p_f}$.

However, $C_p=4.6\cdot10^{-16}\frac{erg}{K^o}$ with $\frac{C_{p_f}}{C_p}=7.2\cdot10^5$. Assuming that $C_p=4.6\cdot10^{-16}\doteq 1.5K+3\frac{m_{At}^2H^*}{r_1^2}\cdot(2r_o)\alpha\,(300)$, H^* becomes $H^*=1.8\cdot10^{23}dycm^2gm^{-2}$ and the field strength $|\psi_{ext}(r_o^+)|$, valid for $r_o<r$, is $|\psi_{ext}(r_o^+)|=H^*(H)^{-1}\cdot|\psi(r_o^-)|=6\cdot10^{-8}\cdot|\psi(r_o^-)|$ and consequently $v(r_o^+)_{es}=2.4\cdot10^{-4}v_{f_{es}}$. Q.E.D.

16. Appendix 6C

By direct computation, for $x\gtrsim 5$, $e^x>>1$. With $\frac{hc_o}{K}=1.4$, $\chi_{em,\lambda}=8\pi\frac{hc_o}{\lambda^5}((\exp\frac{hc_o}{\lambda KT})-1)^{-1}\doteq 8\pi\frac{hc_o}{\lambda^5}(\exp-\frac{hc_o}{\lambda KT})=8\pi\frac{h}{c_o^4}\nu^5(\exp-\frac{h\nu}{KT})$ for $\lambda T\lesssim 0.28$. Also, $\chi_{em}=\int_0^\infty\chi_{em,\lambda}d\lambda=\int_0^\infty\chi_{em,\nu}c_o\nu^{-2}d\nu\doteq 8\pi\frac{h}{c_o^3}\int_0^\infty\nu^3(\exp-\frac{h\nu}{KT})d\nu$. From table of integrals, $\int_0^\infty\nu^3(\exp-\frac{h\nu}{KT})d\nu=6(\frac{KT}{h})^4$ and $\chi_{em}\doteq 48\pi\frac{(KT)^4}{(hc_o)^3}(\frac{erg}{cm^3})$ for $\lambda T\lesssim 0.28$. QED

17. References

6.1 H.E. Roscoe, Spectrum Analysis, p269, (Macmillan and Company, London, 1870)

6.2 J. Norman Lockyer, F.R.S., Studies in Spectrum Analysis, p44, (D. Appleton and

Company, New York, 1878)

6.3 J.J. Thomson, F.R.S., Rays of Positive Electricity, (Longmans, Green and Co., London, 1913)

6.4 T.H. Maiman, Physical Review, Volume 123, Number 4, p1151, August 15, 1961.

6.5 F.K. Richtmyer, E.H. Kennard, T. Lauritsen, Introduction to Modern Physics, P110-113, (McGraw Hill Book Company, Inc. 1955)

6.6 O. Lummer, Verhandlungen de Deutschen Physikalischen Gesellschaft, Volume 1, p 215, 1899.

6.7 F.K. Richtmyer, E.H. Kennard, T. Lauritsen, Introduction to Modern Physics, P131, Fig. 30, (McGraw Hill Book Company, Inc. 1955)