280(7): Discussion of Basic Ideas.

In the simplest theory the conservation of energy and momentum means that:

$$\hbar\omega = \hbar\omega_1 + \hbar\omega_2 \quad -(1)$$

$$\hbar\underline{\kappa} = \hbar\underline{\kappa_1} + \hbar\underline{\kappa_2} \quad -(2)$$

where ω is the incident angular frequency, and ω_1 are the refracted and reflected frequencies. Similarly $\underline{\kappa}$ is the incident wavenumber and $\underline{\kappa_1}$ and $\underline{\kappa_2}$ are the refracted and reflected wave numbers. By the Einstein / de Broglie equations

$$\hbar\omega = \gamma mc^2 \quad -(3)$$

and

$$\hbar\underline{\kappa} = \gamma m\underline{v}. \quad -(4)$$

where m is the mass, $\underline{v}$ the particle velocity and:

$$\gamma = \left(1 - \frac{v^2}{c^2}\right)^{-1/2} \quad -(5)$$

is the Lorentz factor.

The above theory has precisely the same structure as the Compton theory, which is:

$$\hbar\omega + mc^2 = \hbar\omega_1 + \gamma mc^2 \quad -(6)$$

and

$$\hbar\underline{\kappa} = \hbar\underline{\kappa_1} + \hbar\underline{\kappa_2} \quad -(7)$$

In eq. (6) an incoming photon collides with a static electron of rest energy mc^2. The energy of the electron after collision is γmc^2. Compton scattering is a one photon / one electron theory.

2) Therefore ideas for Compton scattering and for reflection and refraction can be used interchangeably. Reflection and refraction can be thought of as a photon colliding with an interface. The collision divides it into two photons. Clearly there is one beam before the collision and two after the collision.

There is no experimental evidence for a photon being completely reflected, or a photon being completely refracted. This idea would mean:

$$\hbar\omega =? \hbar\omega_1 \quad - (8)$$

and

$$\hbar\omega =? \hbar\omega_2 \quad - (9)$$

In the old physics:

$$\omega =? \omega_1 =? \omega_2 \quad - (10)$$

so the old physics would claim that:

$$\hbar\omega =? \hbar\omega_1 = \hbar\omega \quad - (11)$$

and

$$\hbar\omega =? \hbar\omega_2 = \hbar\omega \quad - (12)$$

Eqs. (8) and (9) are violations of Snell's law and of the simple experimental fact that two beams are observed in general, a refracted beam and a reflected beam. So conservation of energy in the old physics demands that a photon can only be reflected or only be refracted, and that eq. (10) is true. However, eq. (10) is counter indicated by the Evans / Morris effects

The condition (10) of the old theory is a

) particular solution of the boundary condition:

$$\omega t - \underline{\kappa} \cdot \underline{r} = \omega_1 t - \underline{\kappa_1} \cdot \underline{r} = \omega_2 t - \underline{\kappa_2} \cdot \underline{r} \quad -(13)$$

for the classical electromagnetic phase.

Clearly, eq. (11) is a particular solution of eq. (13) which implies:

$$\underline{\kappa} \cdot \underline{r} = \underline{\kappa_1} \cdot \underline{r} = \underline{\kappa_2} \cdot \underline{r} \quad -(14)$$

However:

$$\underline{\kappa} = \kappa \left(\underline{i} \sin\theta + \underline{j} \cos\theta \right) \quad -(15)$$

$$\underline{\kappa_1} = \kappa_1 \left(\underline{i} \sin\theta_1 + \underline{j} \cos\theta_1 \right) \quad -(16)$$

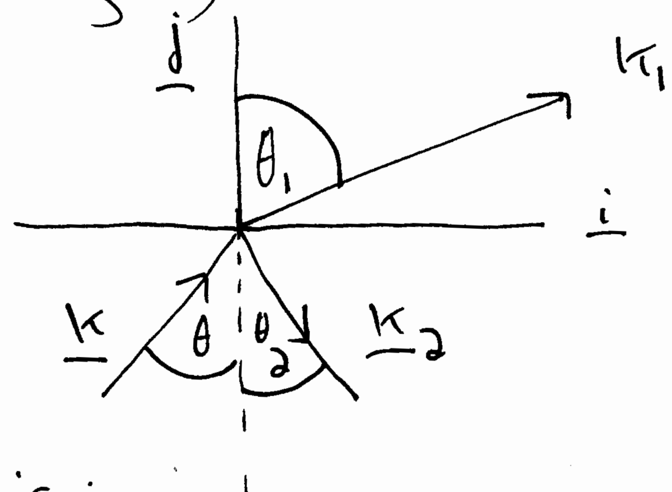
$$\underline{\kappa_2} = \kappa_2 \left(\underline{i} \sin\theta_2 - \underline{j} \cos\theta_2 \right) \quad -(17)$$

and

$$\underline{r} = X \underline{i} + Y \underline{j} \quad -(18)$$

with reference to Fig (1)

Fig(1)



So eq. (14) is:

$$\begin{aligned} & X \kappa \sin\theta + Y \kappa \cos\theta \\ = \; & X \kappa_1 \sin\theta_1 + Y \kappa_1 \cos\theta_1 \\ = \; & X \kappa_2 \sin\theta_2 - Y \kappa_2 \cos\theta_2 \end{aligned} \quad -(19)$$

=

4) In order to obtain the Snell Law (so called) the old physics uses another particular solution:

$$\kappa \sin\theta =? \kappa_1 \sin\theta_1 =? \kappa_2 \sin\theta_2 \quad -(20)$$

so

$$\sin\theta = \sin\theta_2 \quad -(21)$$

because

$$\kappa = \kappa_2 \quad -(22)$$

and

$$\theta = \theta_1 \quad -(23)$$

which is Snell's first law. Snell's second law is obtained from:

$$\kappa \sin\theta =? \kappa_1 \sin\theta_1 \quad -(24)$$

with the assumption:

$$\frac{\kappa_1}{\kappa} =? \frac{n_1}{n} = \left(\frac{\mu_1 \epsilon_1}{\mu \epsilon}\right)^{1/2} \quad -(25)$$

It is easily shown that the assumption (20) is completely incorrect because it implies:

$$\kappa \cos\theta =? \kappa_1 \cos\theta_1 =? -\kappa_2 \cos\theta_2 \quad -(26)$$

so

$$\frac{\kappa_1}{\kappa_2} =? -\frac{\cos\theta_2}{\cos\theta_1} \quad -(27)$$

and

$$\frac{\kappa}{\kappa_2} =? -\frac{\cos\theta_2}{\cos\theta} \quad -(28)$$

For values of θ_1 and θ_2 in the range:

$$0 \leq \theta_1 \leq \pi/2 \quad -(29)$$

and

$$0 \leq \theta_2 \leq \pi/2 \quad -(30)$$

5) eq. (27) shows that the magnitude of $\underline{\kappa}_1$ is negative if the magnitude of $\underline{\kappa}_2$ is positive. This is clearly incorrect and unphysical, QED.

So:

$$\omega = ?\ \omega_1 = ?\ \omega_2 \quad -(31)$$

is incorrect and unphysical and the old boundary condition argument is incorrect and unphysical. The Evans / Morris effects show this clearly.

Therefore eqs. (1) and (2) are the correct equations of conservation of energy and momentum.

The correct development of the boundary condition (13) was first given in Note 279(2):

$$\omega t - \underline{\kappa}\cdot\underline{r} = (\omega_1 + \omega_2)t - (\underline{\kappa}_1 + \underline{\kappa}_2)\cdot\underline{r} \quad -(32)$$

from eqs. (1) and (2). Clearly, eqs. (1) and (2) are true at the boundary and under all conditions.

So:

$$\underline{\kappa} = \underline{\kappa}_1 + \underline{\kappa}_2 \quad -(33)$$

and

$$\underline{\kappa}\cdot\underline{r} = (\underline{\kappa}_1 + \underline{\kappa}_2)\cdot\underline{r} \quad -(34)$$

Experimentally:

$$\theta = \theta_2 \quad -(35)$$

and

$$\sin\theta = \frac{n_1}{n}\sin\theta_1 \quad -(36)$$

6) In general, eq. (34) gives:

$$\kappa_X X + \kappa_Y Y = (\kappa_{X1} + \kappa_{X2}) X + (\kappa_{Y1} + \kappa_{Y2}) Y \quad -(37)$$

where:

$$\kappa_X = \kappa \sin\theta, \quad \kappa_{X1} = \kappa_1 \sin\theta_1, \quad \kappa_{X2} = \kappa_2 \sin\theta_2$$
$$\kappa_Y = \kappa \cos\theta, \quad \kappa_{Y1} = \kappa_1 \cos\theta_1, \quad \kappa_{Y2} = \kappa_2 \cos\theta_2 \quad -(38)$$

Therefore:

$$\kappa (X \sin\theta + Y \cos\theta) = \kappa_1 (X \sin\theta_1 + Y \cos\theta_1) + \kappa_2 (X \sin\theta + Y \cos\theta) \quad -(39)$$

Therefore

$$\boxed{\kappa \neq \kappa_2} \quad -(40)$$

which refutes eq. (22) of the old physics. This is because by conservation of energy and momentum:

$$\boxed{\omega \neq \omega_2} \quad -(41)$$

By Snell's second experimental law:

$$\sin\theta_1 = \frac{n}{n_1} \sin\theta \quad -(42)$$

$$\cos\theta_1 = \left(1 - \left(\frac{n}{n_1}\right)^2 \sin^2\theta\right)^{1/2} \quad -(43)$$

Therefore the two experimental laws are given by eqs. (39) and (42) and (43), and not by the incorrect argument of the old physics. There is no way of deriving the Snell laws from boundary conditions

The average energy of a Planck oscillator is:

$$\langle \hbar\omega \rangle = \frac{\sum_n n\hbar\omega \cdot \exp\left(-\frac{n\hbar\omega}{kT}\right)}{\sum_n \exp\left(-\frac{n\hbar\omega}{kT}\right)} \quad -(44)$$

where

$$n = 0, 1, 2, \ldots, \infty \quad -(45)$$

The Planck oscillator possesses the energy levels:

$$E = n\hbar\omega \quad -(46)$$

The averaging in eq. (44) is the Boltzmann distribution which leads to thermodynamic equilibrium. Here k is the Boltzmann constant and T the temperature of the Planck oscillator. Therefore:

$$\langle \hbar\omega \rangle = \hbar\omega \left(\frac{\sum_n n x^n}{\sum_n x^n} \right) \quad -(47)$$

where:

$$x = \exp\left(-\frac{\hbar\omega}{kT}\right) \quad -(48)$$

At thermodynamic equilibrium the average energy of the Planck oscillator of frequency ω is $\langle \hbar\omega \rangle$.

Now use:

$$\sum_n x^n = 1 + x + x^2 + \ldots = \frac{1}{1-x} \quad -(49)$$

from the Maclaurin series if:

$$x < 1 \quad -(50)$$

Also:

$$\sum_n n x^n = x \frac{d}{dx} \sum_n x^n = x \frac{d}{dx}\left(\frac{1}{1-x}\right) \quad -(51)$$

so

$$\boxed{\langle \hbar\omega \rangle = \left(\frac{x}{1-x}\right)\hbar\omega} \quad -(52)$$

is the average energy of the Planck oscillator at thermal equilibrium at temperature T.

The difference between $\hbar\omega$ and $\langle \hbar\omega \rangle$ is that the oscillator or photon is in the state $n = 1$ in the former case and can be in all states:

$$n = 0, 1, \ldots, m \quad -(53)$$

in the latter case. For microwave radiation at a temperature of $T = 293\,K$:

$$\left.\begin{array}{l} \omega \sim 10^{10}\,Hz, \ \hbar = 1.05459 \times 10^{-34}\,Js \\ T = 293\,K, \ k = 1.38066 \times 10^{-23}\,JK^{-1} \end{array}\right] -(54)$$

so

$$\frac{\hbar\omega}{kT} = 2.61 \times 10^{-4} \quad -(55)$$

So:

$$x = 0.99973 \quad -(56)$$

For visible frequency radiation:

9)

$$\omega \sim 10^{16}\ Hz \quad -(57)$$

so at 293 K:

$$\frac{\hbar\omega}{kT} = 261 \quad -(58)$$

and

$$x \Rightarrow 0 \quad -(59)$$

Using:

$$\frac{x}{1-x} = \frac{1}{e^{\hbar\omega/kT} - 1} \quad -(60)$$

then at visible frequencies:

$$\frac{x}{1-x} \rightarrow e^{-\hbar\omega/kT} = 1 - \frac{\hbar\omega}{kT} \quad -(61)$$

to an excellent approximation.

This is the linear approximation of UFT279 and notes for UFT280. However, in the microwave it is no longer valid.

In order to obtain the experimentally observed black body radiation and density of states the thermal average

$$\langle E \rangle = \langle \hbar\omega \rangle$$

must be used. This is a fundamental hypothesis of the quantum theory. If u denotes the energy density of radiation and N the number density of oscillators then:

$$\langle E \rangle = \langle \hbar\omega \rangle = \frac{\pi c^3}{\omega^2} \frac{du}{d\omega} \quad -(62)$$

and:

$$\boxed{\frac{dU}{d\omega} = \frac{\omega^2}{\pi c^3} \langle \hbar\omega \rangle} \quad -(63)$$

Therefore the energy density of radiation in joules per cubic metre is:

$$U = \frac{1}{\pi c^3} \int \omega^2 \langle \hbar\omega \rangle \, d\omega \quad -(64)$$

and the beam intensity I in watts per square metre is:

$$I = cU = \frac{1}{\pi c^2} \int \omega^2 \langle \hbar\omega \rangle \, d\omega \quad -(65)$$

$$I = \frac{\hbar}{\pi c^2} \int \omega^3 \frac{e^{-\hbar\omega/(kT)}}{1 - e^{-\hbar\omega/(kT)}} \, d\omega \quad -(66)$$

The Stefan Boltzmann is obtained from:

$$I = \frac{\hbar}{\pi c^2} \int_0^\infty \omega^3 \left(\frac{x}{1-x} \right) d\omega$$

$$= \left(\frac{\pi^2 k^4}{15 c^2 \hbar^3} \right) T^4 \quad -(67)$$

It is seen that this result leads to a contradiction in the old theory, because it would mean that the intensities of the reflected and refracted beams must be the same as that of the incident beam. However, the incident beam is divided into two, so its' intensity cannot be the same as that of the reflected and refracted beams.

So the correct theory for the microwave is

$$\left(\frac{x}{1-x}\right) \Sigma\omega = \left(\frac{x_1}{1-x_1}\right) \Sigma\omega_1 + \left(\frac{x_2}{1-x_2}\right) \Sigma\omega_2 \quad -(68)$$

For reflection:

$$n_1^2 \left(\frac{x_1}{1-x_1}\right)^2 \omega_1^2 = \left(\frac{x}{1-x}\right)^2 \omega^2 + \left(\frac{x_2}{1-x_2}\right)^2 \omega_2^2 - \frac{2 x x_2 \omega \omega_2}{(1-x)(1-x_2)} \cos(2\theta) \quad -(69)$$

and for refraction

$$\left(\frac{x_2}{1-x_2}\right)^2 \omega_2^2 = \left(\frac{x}{1-x}\right)^2 \omega^2 + n_1^2 \left(\frac{x_1}{1-x_1}\right)^2 \omega_1^2 - \frac{2 x x_1 n_1 \omega \omega_1}{(1-x)(1-x_1)} \cos(\theta - \theta_1) \quad -(70)$$
