# Bouncing Harmonic Motion and the Compton Effect

Ali F. AbuTaha

Herndon, Virginia, 20271 USA
Tel-Fax: (703) 713-1122

July 21, 1992

"Bouncing" motion has been given little, or no, attention before. We show that bouncing harmonic motion is a crucial mode of orbital motion, and we present some of its striking features. Models of bouncing-orbital motions give direct interpretation of quantum phenomena, such as, the unexpected wavelength shift in the Compton effect. We show how transitions from bouncing to orbital, and orbital to bouncing, motions change the apparent frequency and wavelength of oscillators. We also show how the well-tested Compton-Debye theoretical result, which is derived from lengthy analysis using classical, quantum, and relativistic concepts, is directly derivable from our models.

PACS numbers: 03.20.+i, 03.65.Nk, 03.80.+r

When a perfectly elastic ball is dropped on a perfectly elastic floor from a height, the ball bounces indefinitely (in the absence of air friction, etc.) and its motion can be described by a series of half-cycles (Fig. 1a). If we invert every other half-cycle, we recognize the familiar simple harmonic motion model (Fig. 1b). Further examination reveals other important features.

Consider a ball thrown horizontally with circular orbiting speed, another dropped into a full-tunnel in the earth, and a third ball dropped into a half-tunnel, with a perfectly elastic base as shown in Fig. 2a. The orbiting and the full-tunnel balls oscillate at the same natural frequency, meeting at the starting point once in every cycle (about 84 minutes). The third ball, however, accelerates into the half-tunnel, bounces, and returns to the starting peak twice in every cycle. The analogy between bouncing and orbital motions is clearly made.

If our field of view is limited to only the peak region of the wave, then it will appear to us, and to our detectors, that the bouncing ball oscillates at twice the frequency, or half the wavelength, as the other oscillators; and vice versa. We can be easily perplexed by this behavior, especially if we expect, a priori, identical oscillations, frequencies, and wavelengths for the three particles. This is a startling result as we show later. Let us look at other features of the bouncing motion.

A central body (star, planet, nucleus) can be treated as a mass point because of the relative sizes and distances involved. Bouncing motion is far more likely to occur in electrical and nuclear fields (than in gravitational fields), primarily because of the magnitude of forces in these fields. For example, the electrical attraction in the electron-proton system is about $10^{39}$ times greater than the gravitational attraction. Transition from bouncing to orbital, or orbital to bouncing, motion can happen when external forces are applied. A magnetic force increases or decreases the linear speed of an electron. Then, depending on the magnitude and direction of the magnetic force, bouncing motion can change to elongated, elliptical, or circular orbit, and vice versa (See Fig. 2b).

We now apply our concepts and models to the Compton effect because of its significance, quantitative accuracy and graphic illustration. The momentous experiments by Compton showed that when sharply defined X-rays of wavelength $\lambda$ are scattered by electrons in solids, two distinct wavelengths appear; the incident wavelength itself, or the unmodified line, and a new longer wavelength, or the modified line (Fig. 3). The new wavelength line depends on the scattering angle and is longer for larger scattering angles.[1,2]

The modified wavelength was derived mathematically and explained physically in the Compton-Debye theory. Photons transfer some of their energy in elastic collisions with the electrons. Since the frequency is directly related to energy, E, in $E = h\nu$, it was reasoned that the scattered photons, with lower energy, must have lower frequency ($\nu = E/h$); hence, longer wavelength ($\lambda = 1/\nu$), where h, is Planck's constant.

The mathematical derivation in the Compton-Debye theory is lengthy and it involves classical, quantum, and relativistic considerations. The final result is given by,[1,2]

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

When $\varphi$ is $180^o$, the wavelength doubles, and the frequency is halved. We have found that this result can be derived directly from our models of bouncing harmonic motion and related concepts (see references 3 and 4), as shown next.

The motion of an oscillator in a force field can be described by the familiar equation,

$$m\ddot{x} + kx = F_o \qquad (2)$$

where $F_o$ is a unit-step forcing function, which has the magnitude of the force field itself.[3,4] The general solution is also familiar,

$$x(t) = \frac{F_o}{k} (1 - \cos\varphi) \qquad (3)$$

where, we replace $\omega_n t$ by $\varphi$, where $\omega_n t = \sqrt{k/m}$. We note the striking similarity between the two equations, 1 and 3. The displacement, $x(t)$, is directly related to the wavelength, $\lambda$. It then remains to see whether the value $(F_o/k)$ can be correlated to the Compton-Debye's $(h/m_o c)$, and we find from classical physics that the two values are indeed equivalent:

$$\frac{F_o}{k} = \frac{F_o xt}{kxt} = \frac{kx^2 t}{Ft} = \frac{Et}{mat} = \frac{h}{mv}, \text{ or for } c, = \frac{h}{m_o c} \qquad (4)$$

where, a is acceleration, v is velocity, c is the velocity of light, k is spring constant, and $F = kx$ is Hooke's law. We substitute the rest mass, $m_o$, for m because the velocity of light is used; and we use for energy ($E = Fx = kx^2$), the equivalent value of work, to be consistent with the energy levels in a force field environment.

The Compton-Debye equation applies only to the scattered waves, and it cannot be used to determine an opposite and equal effect on the electron (which gains energy in the collision), nor does it explain the persistence of the original wavelength. Explanations for the presence of the unmodified line after scattering include interactions of the photon with electrons tightly bound in an ionic core. This requires the use of the effective mass of the nucleus itself, which is orders of magnitude greater than the electron mass. These explanations do not provide adequately identifiable phenomenological equivalent from classical physics or natural events.

Bouncing harmonic motion provides an "easy to imagine" physical interpretation for the wavelength shift and the persistence of the original wavelength. When the incident beam is aimed towards the instrument, i.e., at small scattering angles, the instrument's protective cover interferes with electronic excitations into orbital motion (Fig. 4). Only bouncing-related oscillations, directly facing the slit's opening and which have higher frequency and shorter wavelength, enter the collimating slits to the detector. For greater scattering angles (nearly $180^o$), the X-ray beam is pointing away from the detector, and some electrons are excited away from the scatterer into elongated orbital motions as illustrated in Fig. 4. Some of the orbiting electrons, returning from behind the scatterer, and some of the bouncing electrons, in front of the opening, enter the collimating slits together. Two wavelengths are then detected simultaneously. These motions are similar to elastic bouncing balls dropped from a great height and satellites launched directly into elongated orbits with the same height.

We give, yet, another analogy. Consider one of the pockets in a pool table to be the entrance to the collimating slits in the Compton experiment. Billiard balls (electrons) frequently enter the pocket when hit with a cue aimed at the pocket. An expert can achieve the same result, less frequently, by hitting the balls away from the pocket with sufficient reverse-English-spin so that each ball first moves in one direction and then reverses its direction back to the pocket. The X-rays in the Compton experiment take on the role of the cue, the electric field forces (electron-nucleus charge) provide the reverse-spin, and the force field itself sustains the orbiting and bouncing motions, the higher and lower frequencies, and the longer and shorter wavelengths.

We saw in the Compton effect how the measured or calculated frequency can have two distinct values (E/h or 2E/h). A clear distinction as to whether a particle is bouncing or orbiting is crucial to distinguish between the two states. This is of the utmost significance as the consequential 2:1 ratio appears in the measurement of other parameters, including, energy and current. For example, we note that the frequency of the supercurrent in a Josephson's junction is $\nu = 2eV/h$, or $\nu = 2E/h$.[1] Our concepts and models also give direct mathematical derivations and physical interpretations for this and other phenomena, including, the Zeeman effect, the Raman effect, the tunneling effect, Schrodinger's wave function, blackbody radiation, atomic energy levels, and related subjects. Physicists and mathematician may want to apply our models to these and other phenomena. We will report on these subjects in future articles.

---

[1]Parker, S. P., Editor in Chief, "McGraw-Hill Encyclopedia of Physics," McGraw-Hill Book Company, New York, 1983.

[2]Halliday, D. and Resnick, R., "Physics for Students of Science and Engineering," Combined Edition, John Wiley & Sons, Inc., New York, August 1965 (8th printing).

[3]AbuTaha, A. F., "Validity of the General Theory of Relativity," Unpublished paper, July 1992.

[4]AbuTaha, A. F., "Bouncing harmonic motion and oscillations in force fields," Unpublished paper, July 1992.

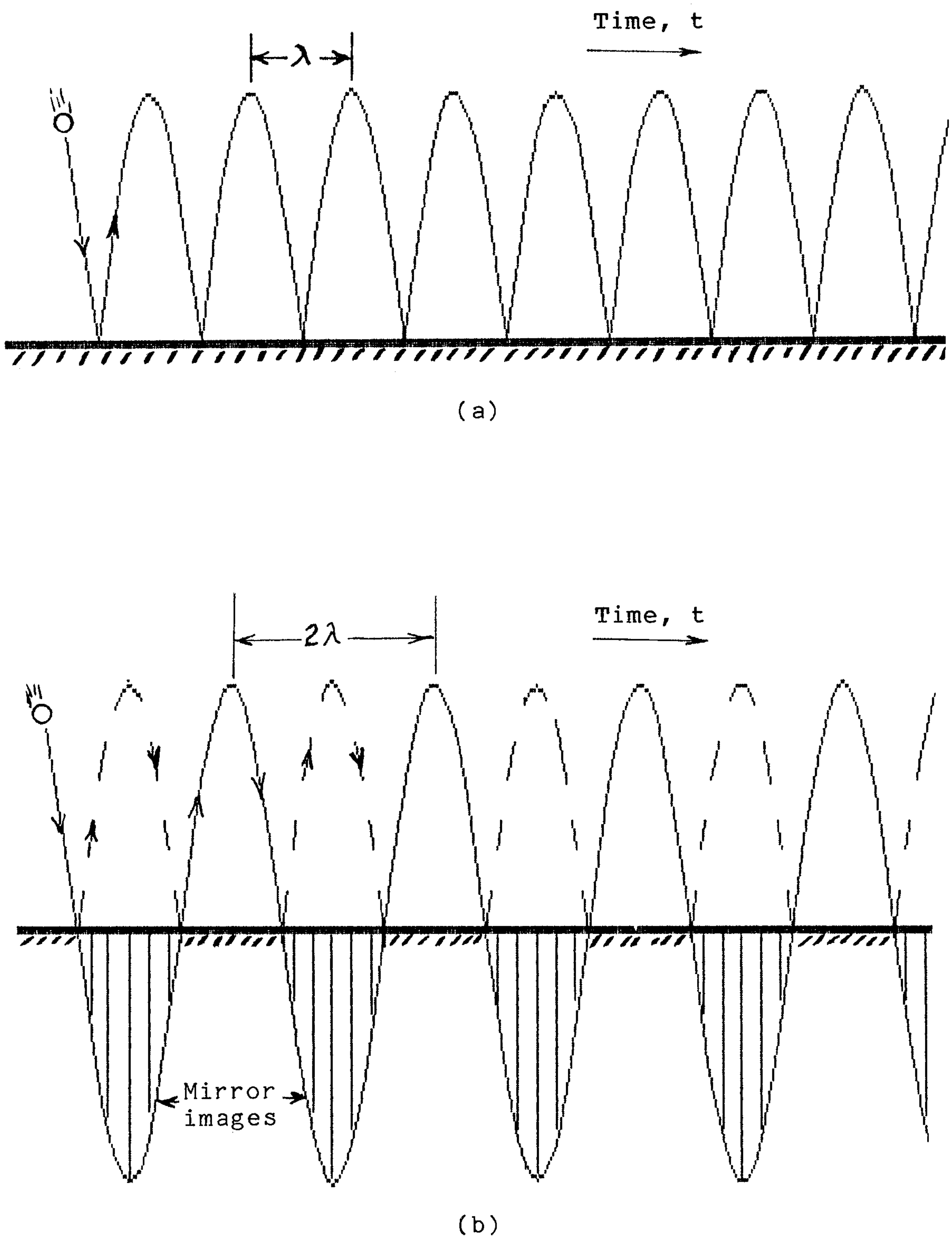



Fig. 1 . Analogy of bouncing motion to simple harmonic motion.

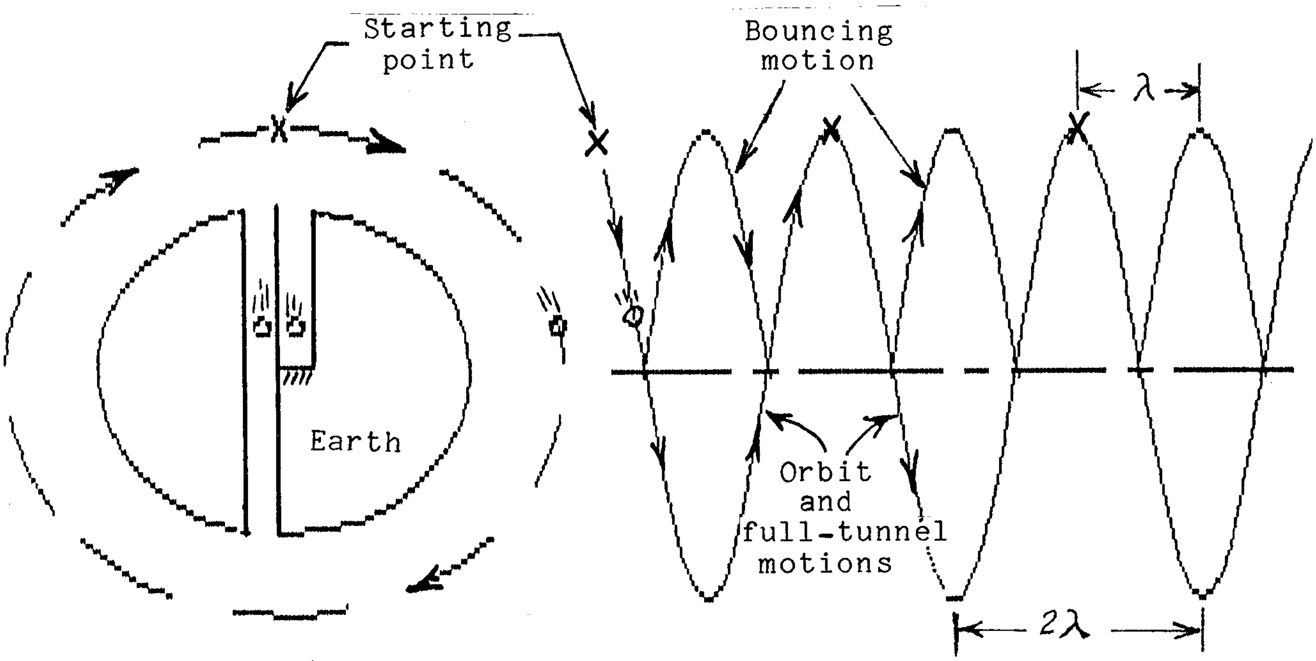



Fig. 2a Bouncing wavelength is half of the analogous orbital wavelength.

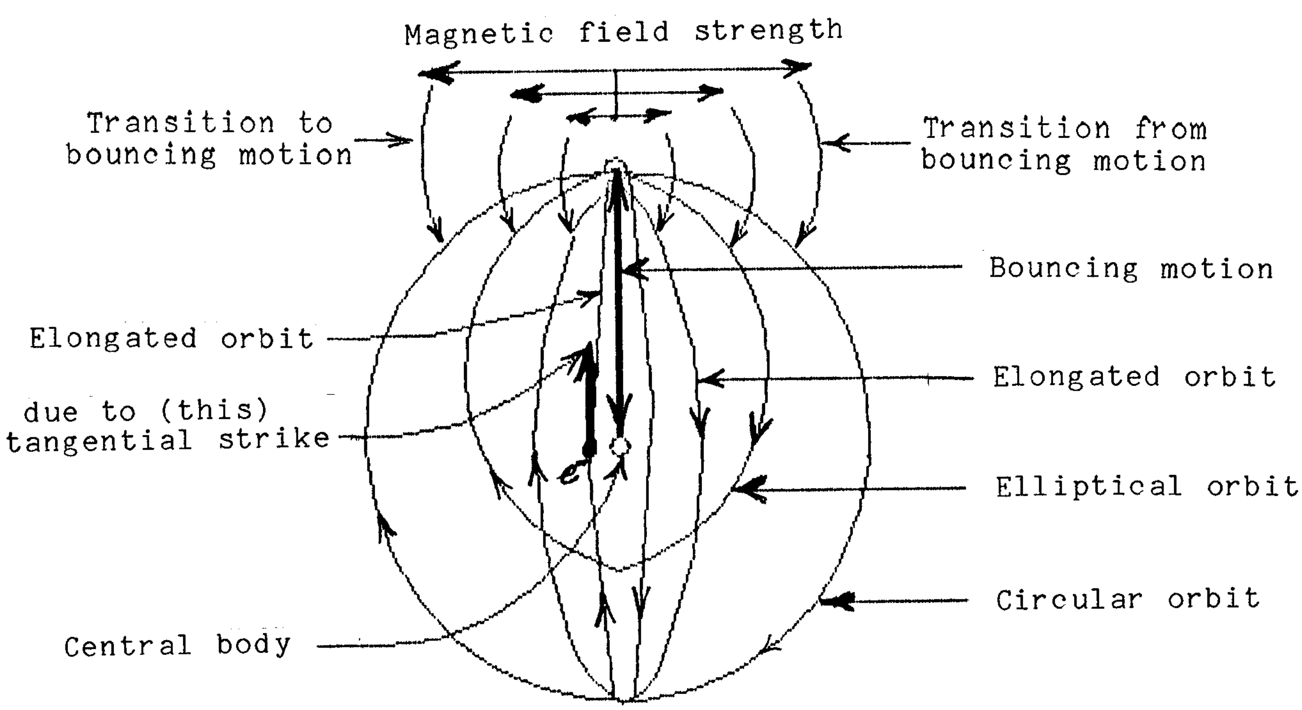
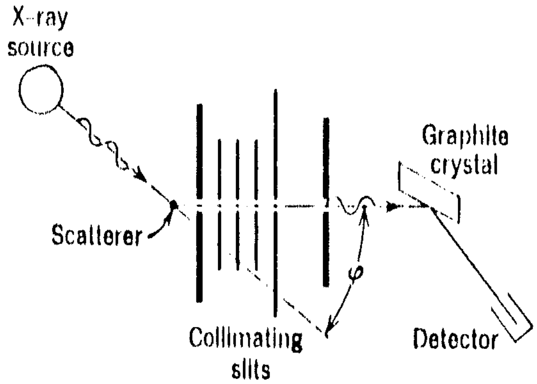
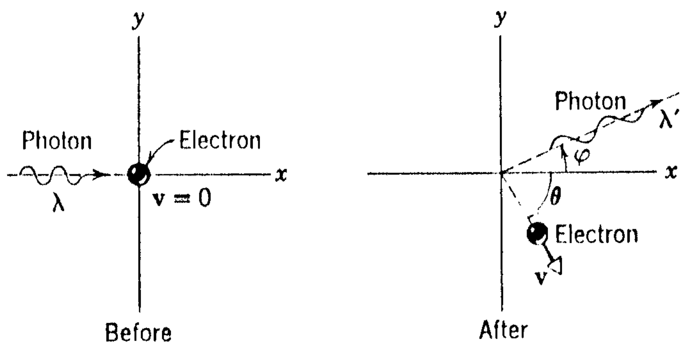


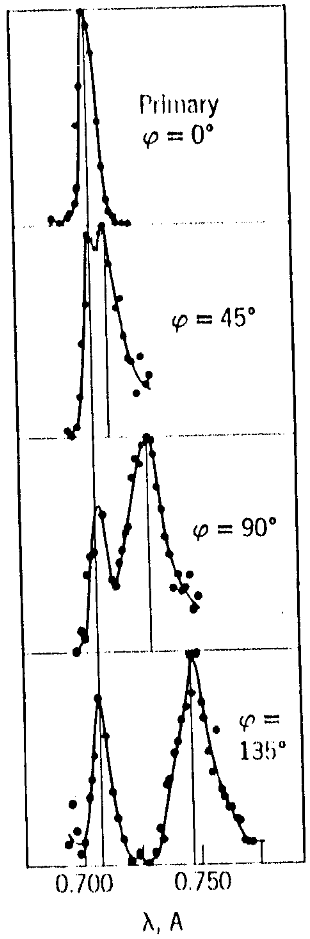

Fig. 2b Transitions between bouncing and orbital motions as a result of an impulse, or field (magnetic) forces.




(a) Compton's historical experiment

(b) Compton-Debye interpretation:
The photon loses energy, therefore, must have lower frequency ($\nu$=E/h), which implies larger wavelength




(b) Compton's results show modified and unmodified $\lambda$ lines.

Fig. 3 Compton's experimental set-up, wavelength shift results, and explanation. Source: Reference 2, pp. 1093, 1094.

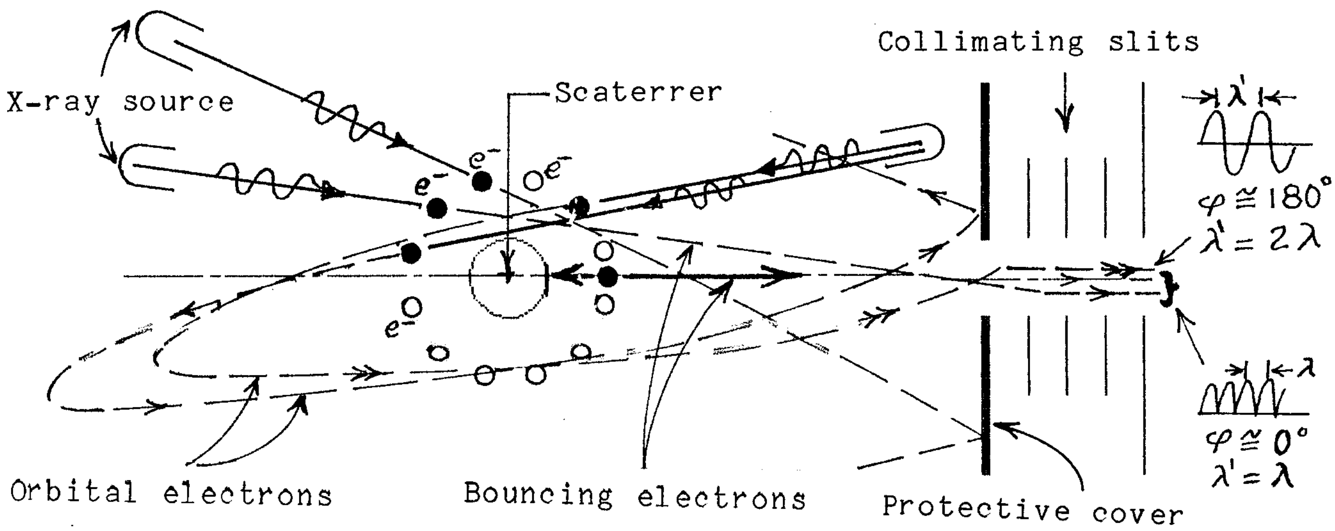
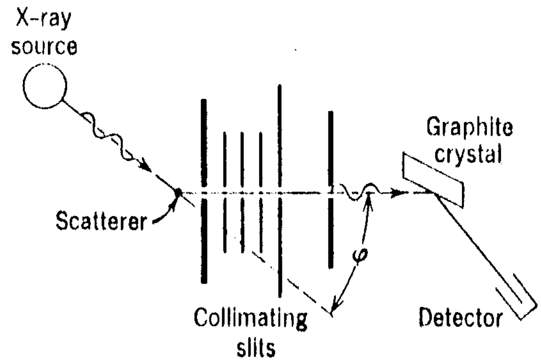
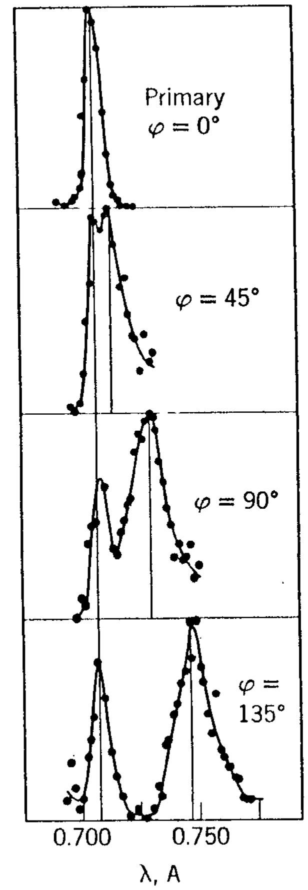
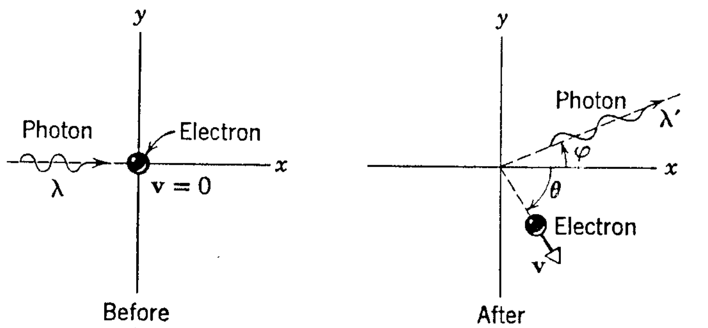



Fig. 4 Interpretation of the Compton wavelength shift using bouncing harmonic motion: Bouncing electrons frequency with shorter $\lambda$ (facing opening) are always detected. Orbital frequency with longer $\lambda$ are only detected when electrons are sent into orbital motion. Protective cover interferes with transition to orbital motion.




(a) Compton's historical experiment

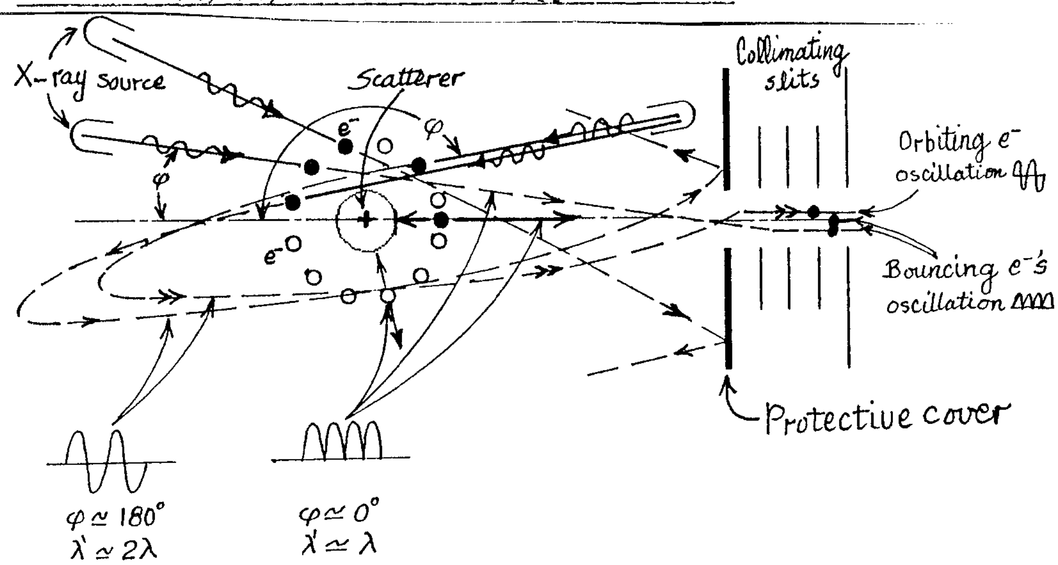



(c) Compton-Debye theoretical interpretation: The photon loses energy, therefore, must have lower frequency ($\nu$=E/h), which implies larger wavelength

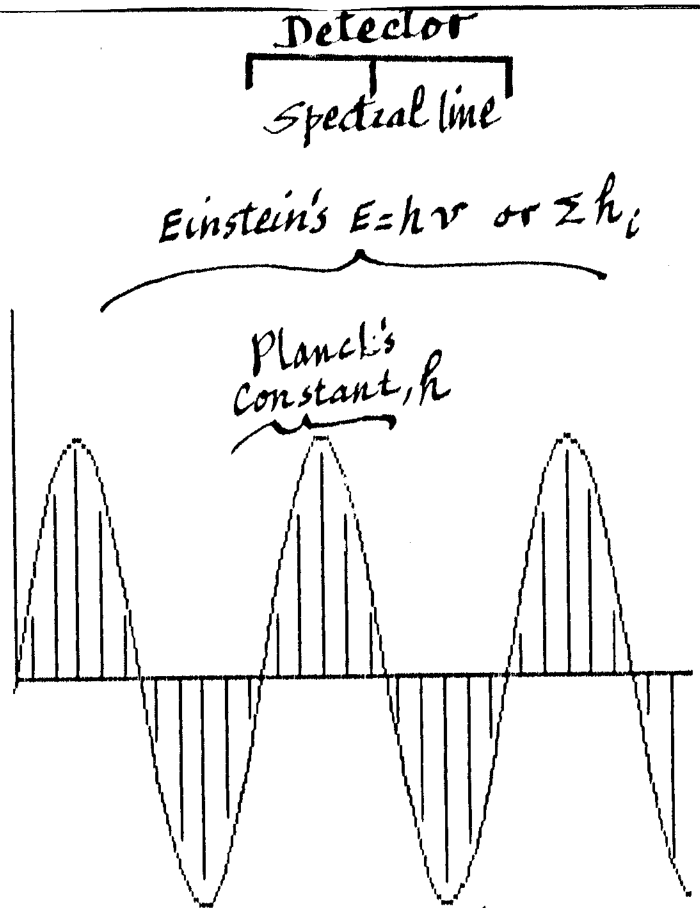
(b) Compton's results show modified and unmodified λ lines.

Source of (a), (b), and (c): Ref. 2, pp. 1093-1094

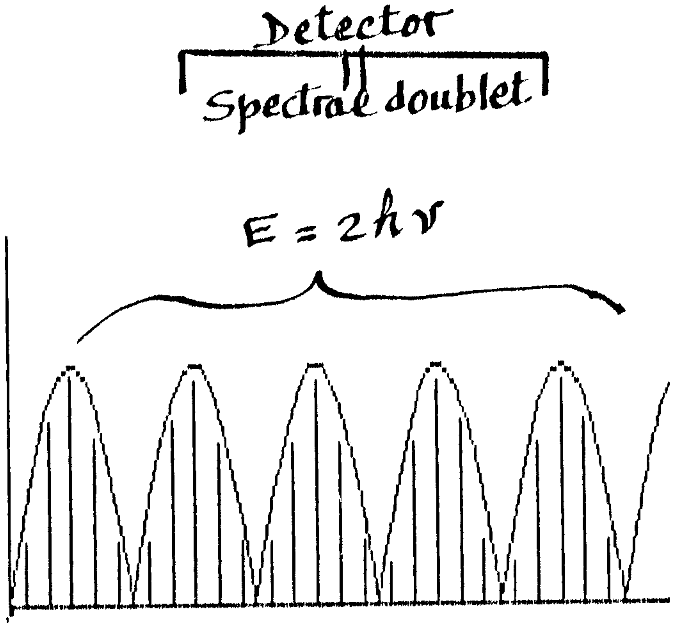



(d) Interpretation of the Compton shift on the basis of: bouncing motion, oscillation in force fields, and dynamic overshoot; bouncing electrons with short λ (facing slits) are always detected, but, orbital oscillations (long λ) are detected only when electrons are sent into orbital motion, just like a communications satellite may be given an energy boost to set it into elongated or elliptical orbit. (A.A.92)

Fig. 5 The Compton Effect

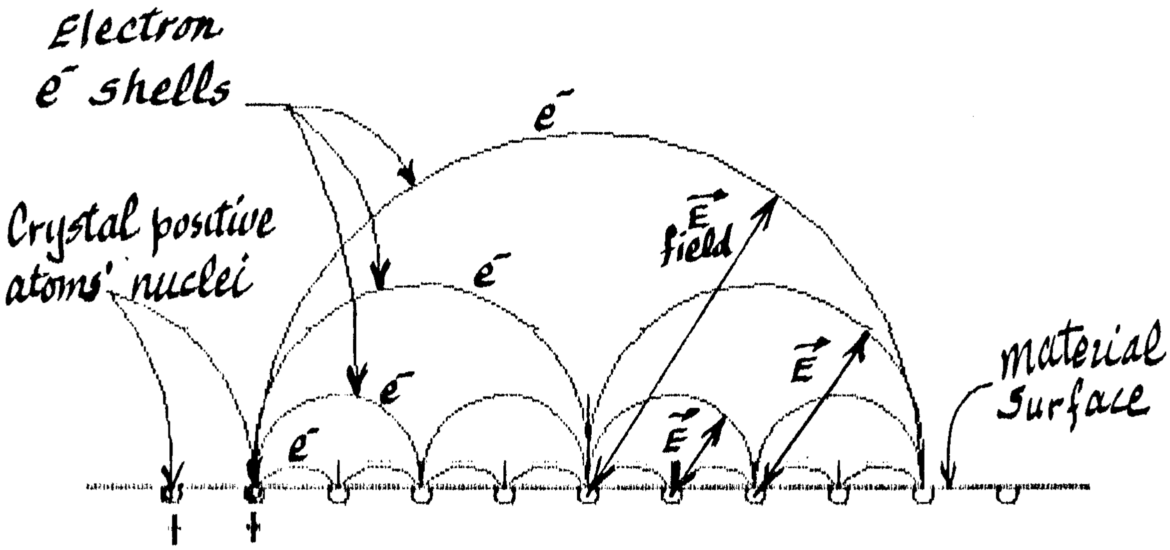



(a) Emission by orbiting electrons ( Compton's effect)




(b) Emission by bouncing electrons ( Superconductivity)

Fig 6. Atomic structure ( cont.)
and energy quanta




(c) A sample model for electrons interactions in molecules and crystals:

- Electric field, $\vec{E}$ (like $\vec{g}$ field for masses) produces dynamic overshoot,
- Dynamic overshoot sustains oscillations,
- Illustrates the dual wave-particle behavior,
- Leads to a direct wave function, $\psi$,
- Explains the behavior of conductors, insulators, and semi-conductors,
- Areas of semi-circles in descending levels is exactly proportional to energy levels in hydrogen atom,
- and, explains many features, properties, and behavior of matter in biological, chemical, and physical systems.

(cont.) Fig. 6 Atomic Structure and electrons' interactions

## Rayleigh Scattering - Thermal - in fluids:

$$r^2 I(\theta)/I_0 = \pi d \lambda^{-4} v^2 (1+\cos^2\theta)(n-1)^2$$

$I(\theta)$ : intensity of light scattered
$\lambda$ : incident beam wavelength
$I_0$ : incident beam intensity
$r$ : distance for intensity $I_0$
$d$ : Number of scattering particles
$v$ : Volume of the disturbing particle
$n$ : index of refraction of the fluid
$\theta$ : scattering angle
$\cos\theta$ : present for unpolarized incident light

## Coulomb scattering - Marsden-Geiger Alpha scattering:

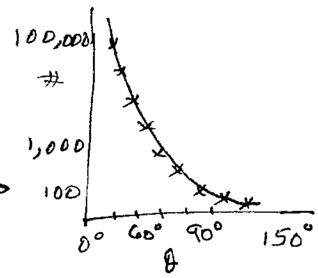
$$\frac{d\sigma}{d\Omega_{pt.}}(\theta) = \left[ Z_1 Z_2 e^2 / 16 \pi \epsilon_0 E \right]^2 \sin^{-4}\theta/2$$

$d\sigma$ : differential cross section
$Z_1 Z_2$ : Atomic numbers (target and projectile)
$e$ : charge
$\epsilon_0$ : permittivity of free space
$E$ : center-of-mass energy of alpha projectile
$\theta$ : center-of-mass scattering or observation angle.

~~Angle of deflection~~ # of flashes $\propto$ inverse-sine-to-4th-power

~~$\theta \propto$~~

$$\# \text{ of flashes} \propto \frac{1}{(\sin\frac{1}{2}\theta)^4}$$




Galileo's: $s = \frac{1}{2}gt$ [redacted] → substitute $\vec{g}$