Determination of the Photon Force and Power

Manjunath. R

#16/1, 8th Main Road, Shivanagar, Rajajinagar, Bangalore560010, Karnataka, India
*Corresponding Author Email: manjunath5496@gmail.com

Abstract: Photons, like all elementary particles, exhibit both wave –like and particle -like properties. The dual nature of photons can be visualized through their interaction with other particles. The photons possess momentum; carry mass during its motion. Hence they also exert force and pressure on other elementary particles. This article describes an equation to measure the force exerted by photon and thus show that photon power is proportional to the force exerted by the photon.

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A photon of energy ($h\upsilon$) associated with the momentum ($p = mc$) collides with an electron of energy ($m_e c^2 < h\upsilon$) associated with the momentum ($p_e = m_e v$). As a result of collision:

- Momentum of the photon decreases from ($p = mc$) to ($p_f = m_f c$)
- Momentum of the electron increases from ($p_e = m_e v$) to ($p_{ef} = m_{ef} v_{ef}$)

From the law of conservation of momentum:

$p + p_e = p_f + p_{ef}$

where: p = initial momentum of the photon (i.e., the momentum of the photon before collision), p_e= initial momentum of the electron (i.e., the momentum of the electron before collision), p_f = final momentum of the photon (i.e., the momentum of the photon after collision) and p_{ef} = final momentum of the electron (i.e., the momentum of the electron after collision).

Since:.

Change in momentum = final momentum – initial momentum

Therefore:

$p_{ef} - p_e = p - p_f$

$\Delta p_e = - \Delta p$

where: $\Delta p_e = (p_{ef} - p_e)$ = change in momentum of the electron and $\Delta p = (p_f - p)$ = change in momentum of the photon

For small change,

$dp_e = - dp$

The wavelength 'λ' of the photon is related to its momentum 'p' by the equation: $\lambda = h / p$

Differentiating the above equation with respect to time, we get:

$d\lambda / dt = (- dp/dt) (h / p^2)$

$d\lambda / dt = (dp_e /dt) (h / p^2)$

The force exerted by photon = rate of change of momentum of the electron

$F = (dp_e /dt)$

$F = (p^2 / h) (d\lambda / dt)$

This equation implies: As more force is exerted by the photon on the electron, the wavelength of the photon increases with time.

Photon power = rate of loss of energy of the photon

Photon power $= - dE/dt = (-dp/dt)\, c = (dp_e /dt)\, c$

Photon power = F c

This equation implies: photon power is proportional to the force exerted by the photon on the electron.

References:

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