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Determination of the Photon Force and Power

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A photon of energy (hυ) 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

$$F = (dp_e /dt)$$

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

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.