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Radiation – Charge Energy Transference Relations

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Abstract: **Change in frequency of radiation is directly proportional to product of charges and inversely proportional to displacement brought from origin.**

Case (i) from infinity

$$(v - v_0)\ \alpha\ \frac{Qq}{x + \Delta x}$$

Case (ii) from x to $(x + \Delta x)$

$$(v - v_0)\ \alpha\ \frac{Qq(\Delta x)}{(x + \Delta x)^2}$$

Keywords: **Radiation, directly proportional, charges.**

1. INTRODUCTION

Electrostatic phenomena arise from the forces that electric charges exert on each other. Coulomb's law quantifies the amount of force between two stationary electrically charged particles. The electric force between charged bodies at rest is conventionally called electrostatic force or Coulomb force[1]

The electrostatic potential Energy V_E of one point charge q at position r in the presence of an electric field E is defined as negative of work W done to bring it from reference position r_{ref} to that position r[2]

Law of conservation of energy states that the total energy of an isolated system remains constant; it is said to be conserved over time[3]

The Planck Constant, or Planck's constant is the quantum of electromagnetic action that relates a photon's energy to its frequency. The Planck constant multiplied by a photon's frequency is equal to a photon's energy[4]

Assumptions:

1. Assume that a photon of energy $h\gamma$ or hc/λ hits a charge q having initial velocity zero attains instantaneous velocity v
2. Consider charge Q at origin stationary and charge q is brought to A without accelerating.
3. Order of charge is out of range of applicable Quantum mechanics.
4. Order of mass of charge is out of range of applicable quantum mechanics
5. $x >>> \Delta x$
6. $Qq > 0$ if $Qq < 0$ take $|Qq|$ i.e. work is always done against the electric field or field causing attraction forces (if any)
7. Only electrostatic forces is experienced between charges Q and q
8. Consider charge Q at origin stationary and charge q is brought to B from A without accelerating.

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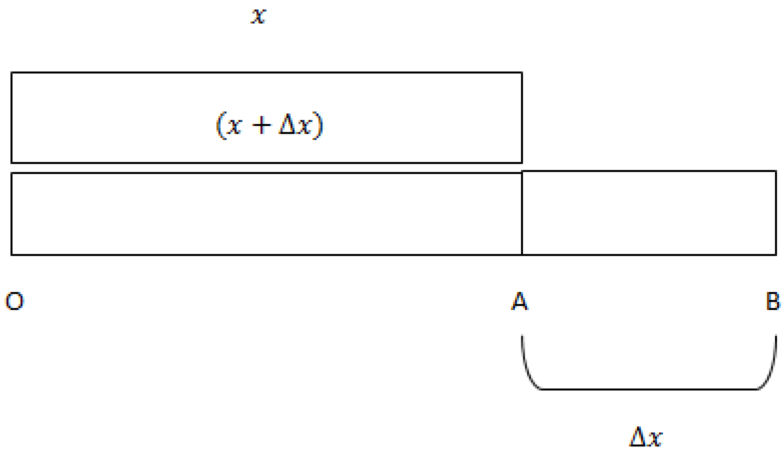
2. METHODS

[1]



$\overline{\mathrm{OA}} = x$

$\overline{\mathrm{AB}} = \Delta x$

$\overline{\mathrm{OB}} = (x+\Delta x)$

Let $g(x) = \int_{\infty}^{x} F.dx$

And $U(x) = Potential\ Energy\ at\ x$

$$= -\int_{\infty}^{x} F.dx = \frac{+Qq}{4\pi\varepsilon_0\, x}$$

$$F = Electrostatic\ force = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{x^2}$$

$\therefore g(x)$iscontinuous, itisdifferentiable

Using $g(x) = \lim_{\Delta x \to 0} \frac{g(x+\Delta x)-g(x)5}{\Delta x}$

$\Rightarrow \frac{d}{dx} g(x) = \lim_{\Delta x\to 0} \frac{g(x+\Delta x)-g(x)}{\Delta x}$

$\Rightarrow \frac{d}{dx}\left[\int_{\infty}^{x} F.dx\right] = \lim_{\Delta x\to 0} \frac{g(x+\Delta x)-g(x)}{\Delta x}$

$\Rightarrow F(at\ x+\Delta x) = \lim_{\Delta x\to 0} \frac{g(x+\Delta x)-g(x)}{\Delta x}$

$\Rightarrow \left[F_{(x+\Delta x)} \mathrm{x}\ \Delta x\right] = \int_{\infty}^{x+\Delta x} \frac{Qq.dx}{4\pi\varepsilon_0 (x+\Delta x)^2} - \int_{\infty}^{x} \frac{Qq.dx}{4\pi\varepsilon_0 (x)^2}$

$\Rightarrow \left[F_{(x+\Delta x)}\Delta x\right] = U_x - U_{(x+\Delta x)}$

$\Rightarrow -U_{(x+\Delta x)} = \frac{Qq}{4\pi\varepsilon_0}\left[\frac{\Delta x}{(x+\Delta x)^2} - \frac{1}{x}\right]$

$\Rightarrow -U_{(x+\Delta x)} = \frac{Qq}{4\pi\varepsilon_0}\left[\frac{x\Delta x-(x+\Delta x)^2}{x(x+\Delta x)^2}\right]$

$\Rightarrow -U_{(x+\Delta x)} = \frac{Qq}{4\pi\varepsilon_0}\left[\frac{x\Delta x - x^2 - 2x\Delta x}{x(x+\Delta x)^2}\right]$

$\Rightarrow -U_{(x+\Delta x)} = \frac{Qq}{4\pi\varepsilon_0}\left[\frac{x^2+x\Delta x}{x(x+\Delta x)^2}\right]$

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$$\Rightarrow -U_{(x+\Delta x)} = \frac{Qq}{4\pi\varepsilon_0}\left[\frac{x(x+\Delta x)}{x(x+\Delta x)^2}\right]$$

$$\Rightarrow \boxed{-U_{(x+\Delta x)} = \frac{Qq}{4\pi\varepsilon_0(x+\Delta x)} \rightarrow ②}$$

$$\Rightarrow U_{(x+\Delta x)} - U_x = -F_{(x+\Delta x)}\Delta x$$

$$\Rightarrow \boxed{\Delta U = -F_{(x+\Delta x)}\Delta x} \qquad \rightarrow ①$$

$$\boxed{U_{(x+\Delta x)} = -F_{(x+\Delta x)}\Delta x + U_x}$$

[2] According to assumptions ① and ②

∴ Work done is conservative

Using law of Conservative Energy

$\Delta KE = -\Delta PE$

$$\therefore V_{initial} = 0$$

$$V_{final} = V$$

$$\frac{1}{2}mv^2 = -\left[-F_{(x+\Delta x)}\Delta x + U_{(x)}\right](\text{from eq. } 2)$$

$$\Rightarrow \quad \frac{1}{2}mv^2 = \frac{Qq}{4\pi\varepsilon_0(x+\Delta x)} \rightarrow ③$$

$$\Rightarrow \quad V_{max} = \sqrt{\frac{2Qq}{4\pi\varepsilon_0(x+\Delta x)m}}$$

Using conservation of energy law

$\Delta KE = \Delta h\gamma$

Where $h\gamma$ = energy of radiation

Case (i) when collision is elastic

$$\Rightarrow \quad KE = h\gamma$$

$$\Rightarrow \quad \frac{1}{2}mv^2 = h\gamma$$

Using Equation ③

$$\frac{Qq}{4\pi\varepsilon_0(x+\Delta x)} = h\gamma$$

$$\Rightarrow v\ \alpha \left(\frac{Qq}{x+\Delta x}\right) \text{ or } v = \left(\frac{Qq}{4\pi\varepsilon_0 h(x+\Delta x)}\right)$$

From assumption ① and equation ③

$$\frac{1}{\lambda}\alpha\frac{Qq}{(x+\Delta x)} \text{ or } \frac{1}{\lambda} = \frac{Qq}{4\pi\varepsilon_0(x+\Delta x)hc}$$

and $v\ \alpha \sqrt{\frac{v}{m}}\ or\ v = \sqrt{\frac{2hv}{m}}$

Case (ii) if collision is inelastic

$\Rightarrow \Delta KE = \Delta h\gamma$

$\Rightarrow KE = h(\gamma - \gamma_0)$

Where hv_0 = energy absorbed

v_0 = frequency of radiation absorbed

$\Rightarrow h(\gamma - \gamma_0) = \frac{1}{2}mv^2$

$\Rightarrow v\alpha\sqrt{\frac{\gamma-\gamma_0}{m}}$ or $v\alpha\sqrt{\frac{2h(\gamma-\gamma_0)}{m}}$

From equation ③

$$\frac{Qq}{4\pi\varepsilon_0(x+\Delta x)} = h(\gamma - \gamma_0)$$

$\Rightarrow (\gamma - \gamma_0)\alpha\frac{Qq}{(x+\Delta x)}$ or $(\gamma - \gamma_0) = \frac{Qq}{4\pi\varepsilon_0(x+\Delta x)h}$

From assumption ① and equation ③

$$\frac{hc}{\lambda} - \frac{hc}{\lambda_0} = \frac{Qq}{4\pi\varepsilon_0(x+\Delta x)}$$

$\Rightarrow \frac{1}{\lambda} - \frac{1}{\lambda_0}\alpha\frac{Qq}{(x+\Delta x)}$ or $\frac{1}{\lambda} - \frac{1}{\lambda_0} = \frac{Qq}{4\pi\varepsilon_0(x+\Delta x)hc}$

Where λ_0 = wavelength of radiation absorbed

$\frac{hc}{\lambda_0}$ = energy of radiation absorbed

[3] According to assumptions ⑧ and ①

∴ Work done is conservative

Using law of conservation of Energy

$\Delta KE = \Delta PF$

$\frac{1}{2}mv^2 = -[-F_{(x+\Delta x)}\Delta x]$ equation ①

$\frac{1}{2}mv^2 = \frac{Qq(\Delta x)}{4\pi\varepsilon_0(x+\Delta x)^2}$ →④

$\Rightarrow v\alpha\sqrt{\frac{Qq\Delta x}{m(x+\Delta x)^2}}$ or $V_{max} = \sqrt{\frac{2Qq(\Delta x)}{m4\pi\varepsilon_0(x+\Delta x)^2}}$

Using Law of Conservation of Energy

$\Delta KE = \Delta h\gamma$

Case (i) when collision is elastic

$\Rightarrow \frac{1}{2}mv^2 = h\gamma$

From equation ④

$$h\gamma = \sqrt{\frac{2Qq(\Delta x)}{4\pi to(x+\Delta x)^2}}$$

$\Rightarrow v\alpha\frac{Qq(\Delta x)}{(x+\Delta x)^2}$ or $v = \frac{Qq(\Delta x)}{4\pi\varepsilon_0 h(x+\Delta x)^2}$

$$v\alpha\sqrt{\frac{\gamma}{m}} \text{ or } v=\sqrt{\frac{2h\gamma}{m}}$$

From assumption ① and equation ④

$$h\gamma=\frac{hc}{\lambda}\Rightarrow\frac{hc}{\lambda}=\frac{Qq(\Delta x)}{4\pi to(x+\Delta x)^2}$$

$$\Rightarrow\frac{1}{\lambda}\alpha\frac{Qq(\Delta x)}{(x+\Delta x)^2}\ or\ \frac{1}{\lambda}=\frac{Qq(\Delta x)}{4\pi\varepsilon_0 hc(x+\Delta x)^2}$$

Case (ii) when collision is inelastic

$$\frac{1}{2}mv^2=h(\gamma-\gamma_0)$$

$$\Rightarrow v\alpha\sqrt{\frac{\gamma-\gamma_0}{m}}\ or\ v=\sqrt{\frac{2h(\gamma-\gamma_0)}{m}}$$

From equation ④

$$(\gamma-\gamma_0)=\frac{Qq(\Delta x)}{4\pi\varepsilon_0 h(x+\Delta x)^2}$$

$$(\gamma-\gamma_0)\alpha\frac{Qq(\Delta x)}{(x+\Delta x)^2}\ or\ (\gamma-\gamma_0)=\frac{Qq(\Delta x)}{4\pi\varepsilon_0 h(x+\Delta x)^2}$$

$$\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)\ \alpha\ \frac{Qq(\Delta x)}{(x+\Delta x)^2}\ or\ \left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)=\frac{Qq(\Delta x)}{4\pi\varepsilon_0 hc(x+\Delta x)^2}$$

3. RESULT

1. Change in reciprocal wavelength (λ^{-1})or frequency (v) of radiation is directly proportional to product of charges and inversely proportional to distance from origin

(i) From infinity: $\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)\ \alpha\ \frac{Qq}{x+\Delta x}$

(ii) From x to $(x+\Delta x)$: $\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)\ \alpha\ \frac{Qq\Delta x}{(x+\Delta x)^2}$

2. Maximum velocity that could be attained is directly proportional to square root of product of mass of charge and distance from origin

(i) From infinity: $V_{max}\alpha\sqrt{\frac{Qq}{m(x+\Delta x)}}$

(ii) From $x\ to\ (x+\Delta x)$: $V_{max}\alpha\sqrt{\frac{Qq(\Delta x)}{m(x+\Delta x)^2}}$

(iii) Potential Energy difference between two points is equal to electrostatic force applied at final point into displacement brought.

APPENDIX

γ: frequency of radiation

γ_0: frequency of radiation absorbed

λ: wavelengthof radiation

λ_0: wavelength of radiation absorbed

v: velocity of charge q

m: mass of charge q

Q: Stationary charge value

q: Value of charge undergoing interactions

$$h: \text{Planck's constant} = 6.626x10^{-34}\, {}^{\text{J}}/_{\text{s}}$$

ε_0: Permittivity of free space $= 8.854x10^{-12}\, {}^{\text{Farad}}/_{\text{m}}$

$(4\pi\varepsilon_0)^{-1}$: Constant of proportionally Coulomb Force $= 9x10^9\ \text{Kgm}^3\text{s}^{-4}\text{A}^{-2}$

c: Speed of light = $3x10^8\, {}^{\text{m}}/_{\text{s}}$

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