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Derivation of QE Formula

1 Purpose

Derive formula for photocathode QE:

$$QE = \frac{124 \cdot I\,(\mathrm{mA})}{P\,(\mathrm{W})\,\lambda\,(\mathrm{nm})}$$

2 Derivation

By definition,

$$QE = \frac{N_{e^-}}{N_\gamma} \tag{1}$$

where N_{e^-} is the number of electrons emitted and N_γ is the number of photons incident on the photocathode. For a uniform laser (fixed wavelength λ and power P), the laser power in some time interval t is given by

$$P\,(W) = \frac{EN_\gamma}{t} = \frac{hc}{\lambda}\frac{N_\gamma}{t} \tag{2}$$

since $E_\gamma = \dfrac{hc}{\lambda}$ is the energy of a photon with wavelength λ. Solving for N_γ yields

$$N_\gamma = \frac{P\lambda t}{hc} \tag{3}$$

When the photons strike the photocathode in some area, some number N_{e^-} of electrons will be emitted. The SI unit of current I is the ampere, which is one coulomb per second, and can be related to electrons per second when noting that one coulomb is equivalent to the charge of 6.242×10^{18} electrons and so

$$N_{e^-} = It \times \left(\frac{6.242 \times 10^{18}\ \text{electrons}}{1\ \text{Coulomb}}\right) \tag{4}$$

Dividing (4)by (3) yields the equation for QE:

$$\begin{aligned}
\frac{N_{e^-}}{N_\gamma} &= It \times \left(\frac{6.242 \times 10^{18}\ \text{electrons}}{1\ \text{Coulomb}}\right)\frac{hc}{P\lambda t} \\
&= \frac{Ihc\left(6.242 \times 10^{18}\right)}{P\lambda} \\
&= \frac{I\,(\mathrm{A}) \times \left(6.242 \times 10^{18}\right)\left(6.626 \times 10^{-34}\mathrm{J\,s}\right)\left(2.998 \times 10^{8}\,\frac{\mathrm{m}}{\mathrm{s}}\right)}{P\,(\mathrm{W})\,\lambda\,(\mathrm{m})} \\
&\approx \frac{124 \times I\,(\mathrm{mA})}{P\,(\mathrm{W})\,\lambda\,(\mathrm{nm})}
\end{aligned}$$

I conveted to mA and nm in the last step.