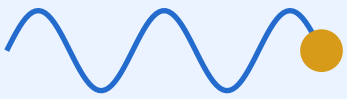
PEARSON EDEXCEL IAL PHYSICS | UNIT 2

LESSON 2.1.5

Photons, Photoelectric Effect and de Broglie Wavelength

Light transfers energy in photons, while moving particles can also show a measurable wavelength.

ONE PHOTON



$E = hf$

higher frequency means more energy per photon

PHOTON ENERGY

FREQUENCY FORM

$E = hf$

h = Planck constant

WAVELENGTH FORM

$E = hc/\lambda$

because $c = f\lambda$

ELECTRONVOLT

$1\ eV = 1.60 \times 10^{-19}\ J$

energy gained through 1 V

WORKED PHOTON EXAMPLE

Find the energy of a 500 nm photon in joules and electronvolts.

1 CONVERT λ

$500\ nm = 5.00 \times 10^{-7}\ m$

2 CALCULATE E

$E = hc/\lambda = 3.98 \times 10^{-19}\ J$

3 CONVERT TO eV

$E = 3.98/1.60 = 2.49\ eV$

THE TWO MODELS

WAVE MODEL

Explains diffraction and interference.

PHOTON MODEL

Explains energy transfer in discrete packets.

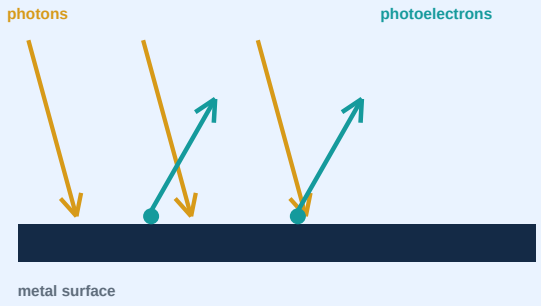
KEY IDEA

Increasing intensity adds more photons per second. Increasing frequency raises the energy of every photon.

1 The photoelectric effect

One photon transfers its energy to one electron. Emission occurs only when photon energy reaches the metal's work function.

ENERGY ACCOUNTING



EINSTEIN EQUATION

$$hf = \varphi + K_{max}$$

$$K_{max} = 1/2\ mv^2_{max}$$

$$f_0 = \varphi/h$$

ϕ = work function; f0 = threshold frequency

WHAT THE EXPERIMENT SHOWS

BELOW f0

No electrons are emitted, however intense the light becomes.

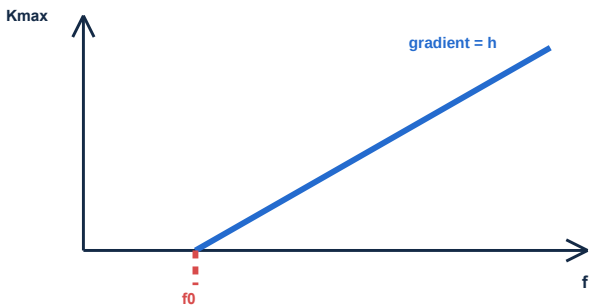
FREQUENCY ABOVE f0

Higher frequency gives greater maximum kinetic energy.

GREATER INTENSITY

More photons give more electrons per second, if f is above f0.

THE MAXIMUM-KINETIC-ENERGY GRAPH



GRADIENT	Planck constant h
X-INTERCEPT	threshold frequency f0
Y-INTERCEPT	-work function, -ϕ

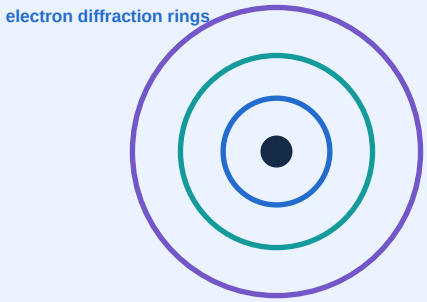
EVIDENCE FOR PHOTONS

Immediate emission and a threshold frequency are explained by one-electron, one-photon energy transfers.

2 Matter waves and discrete energy levels

Electron diffraction shows that particles can behave as waves. Atomic line spectra show that electrons occupy discrete energy levels.

DE BROGLIE WAVELENGTH



a diffraction pattern reveals wave behaviour

MATTER-WAVE EQUATION

$$\lambda = h/p$$

for non-relativistic particles:

$$p = mv$$

larger momentum means shorter wavelength

WORKED ELECTRON EXAMPLE

An electron has momentum $p = 3.00 \times 10^{-24}$ kg m s^{-1}.

$\lambda = h/p = (6.63 \times 10^{-34})/(3.00 \times 10^{-24})$

$\lambda = 2.21 \times 10^{-10}$ m

WAVE-PARTICLE DUALITY

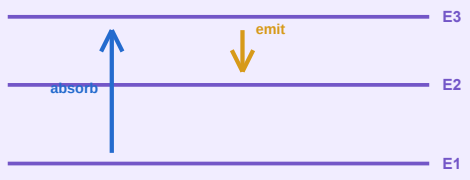
LIGHT

Diffraction supports the wave model; photoelectric emission supports the photon model.

ELECTRONS

They arrive as particles but form diffraction patterns collectively.

ATOMIC LINE SPECTRA



photon energy: $\Delta E = hf$

Emission: an electron moves down and releases a photon. Absorption: a photon of exactly the required energy moves an electron up.

$\Delta E = hf = hc/\lambda$

A line spectrum is discrete because only specific energy differences are allowed.