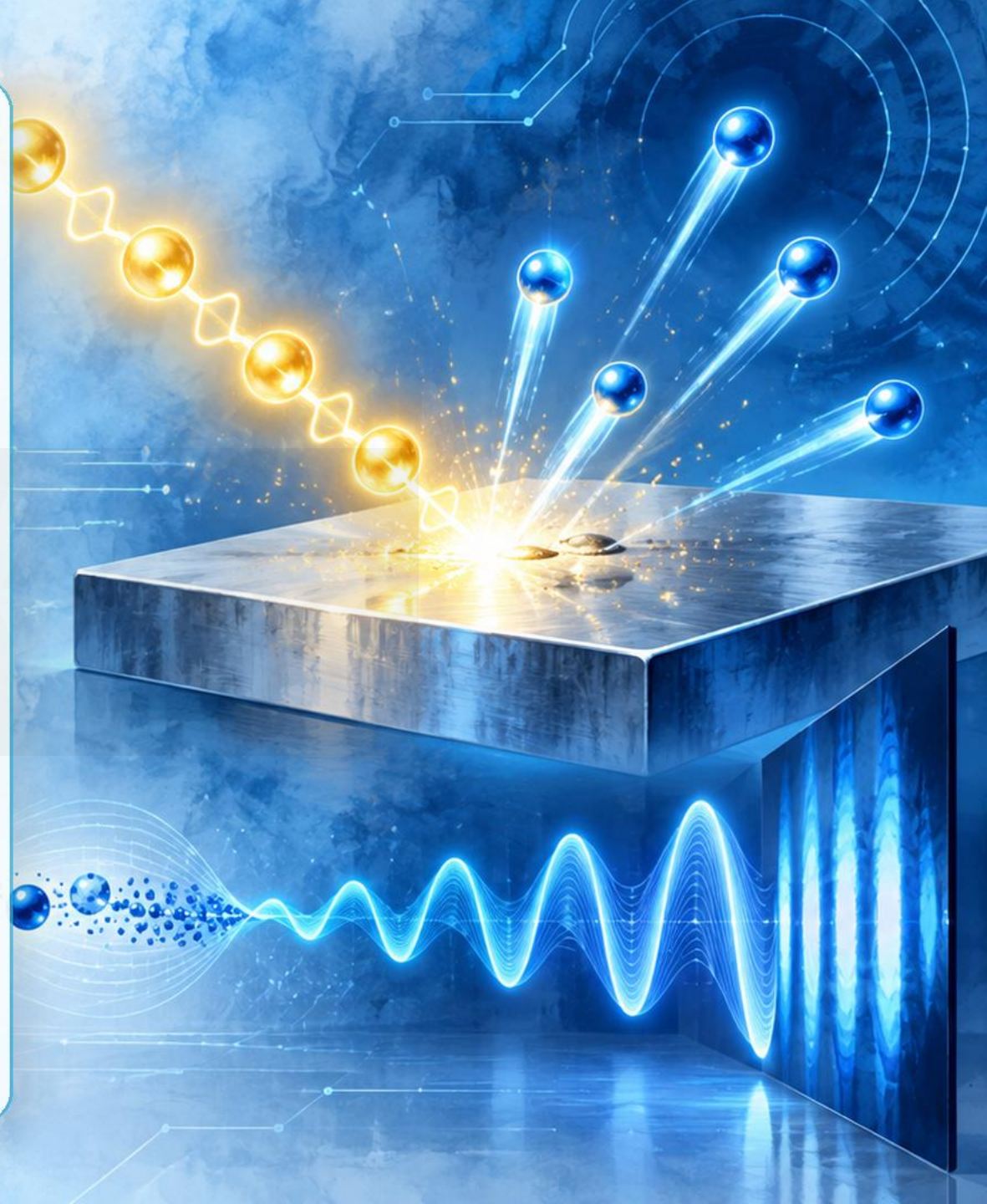


PHYSICS • CLASS 12

CHAPTER 11

Dual Nature of Radiation and Matter

CHAPTER NOTES



DUAL NATURE OF RADIATION & MATTER

Light and matter reveal wave or particle behaviour according to how they are observed.

① ELECTRONS AND EMISSION

- Metals contain mobile conduction electrons.
- They can be emitted when they gain sufficient energy.
- Emitted electrons carry kinetic energy and momentum.

$$K_{\max} = \frac{1}{2} m_e v_{\max}^2$$

② PHOTOELECTRIC EXPERIMENTS

- Light incident on a metal ejects electrons only if $\nu \geq \nu_0$.
- Stopping-potential magnitude V_0 measures maximum kinetic energy.
- $K_{\max} = eV_0$ (independent of intensity). Experiment shows particle-like transfer of energy.

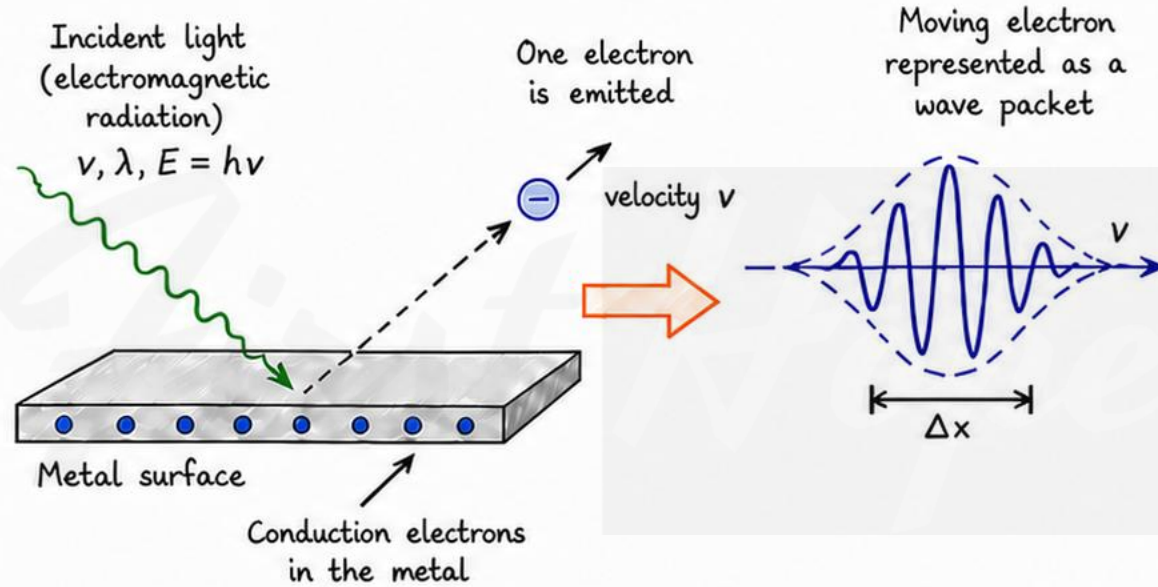
Wave phenomena describe propagation (interference, diffraction, polarisation)

From waves to particles to waves again

Photons describe discrete energy-momentum transfer
 $E = h\nu, p = \frac{h}{\lambda}$

Moving matter has wavelength
 $\lambda = \frac{h}{p}$

Light-matter interaction overview



③ PHOTONS AND EINSTEIN'S EQUATION

- Radiation transfers energy in discrete quanta (photons) during interactions.
- Each photon has energy $E = h\nu$ and momentum $p = \frac{h}{\lambda}$.
- Einstein's photoelectric equation:
$$h\nu = \phi + K_{\max} = \phi + eV_0$$
Where $\phi = h\nu_0$ is the work function.

④ DE BROGLIE MATTER WAVES

- A moving particle of momentum p is associated with wavelength
$$\lambda = \frac{h}{p}$$
- De Broglie matter waves describe moving particles.

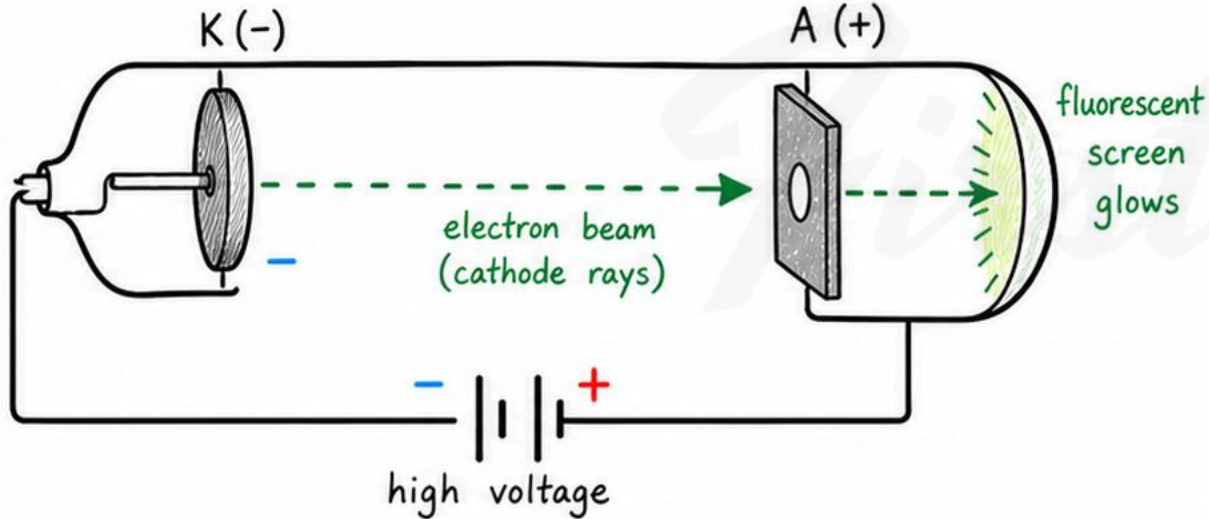
SCOPE OF DUAL NATURE

Wave evidence	Photon evidence
✓ Interference	✓ Photoelectric effect
✓ Diffraction	✓ Compton scattering (light-electron)
✓ Polarisation	

Observations decide the revealed nature: wave for propagation phenomena, particle for discrete interactions.

CATHODE RAYS & THE ELECTRON

In a low-pressure discharge tube, a high voltage between the cathode (K) and anode (A) produces a beam of cathode rays. The cathode rays are fast, negatively charged particles (electrons) that travel from the negative cathode to the positive anode and pass through the anode aperture to strike a fluorescent screen, making it glow.



Cathode rays are deflected by electric fields and by magnetic fields, showing that they are charged particles.

The tube is evacuated to a very low pressure:
about 0.001 mm Hg ($\approx 10^{-3}$ torr)

EVIDENCE 1: SPEED

In Thomson's experiments, the speed of cathode rays was typically about 0.1c to 0.2c.

$$0.1c \text{ to } 0.2c \approx (3.0 \times 10^7 \text{ to } 6.0 \times 10^7) \text{ m s}^{-1}$$

EVIDENCE 2: SPECIFIC CHARGE

From deflection measurements, Thomson found the magnitude of the specific charge to be

$$\frac{|q|}{m_e} \approx 1.76 \times 10^{11} \text{ C kg}^{-1}$$

This value is the same for all cathode materials and for all gases, showing the electron is a universal constituent of matter.

EVIDENCE 3: QUANTIZED CHARGE

Millikan's oil-drop experiments showed that charge occurs in integer multiples of e :

$$q = n e, \quad n = 0, \pm 1, \pm 2, \dots$$

Thus, the charge on the electron is

$$q_e = -e$$

CONSTANTS

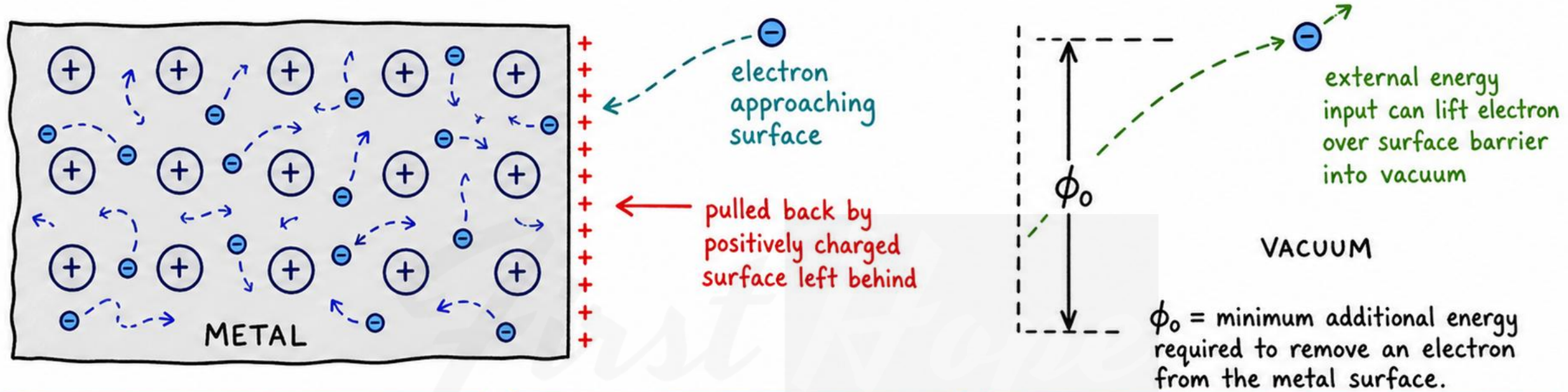
Elementary charge

$$e = 1.602176634 \times 10^{-19} \text{ C} \\ (\text{exactly})$$

Electron mass

$$m_e = \frac{e}{(|q|/m_e)} \\ \approx 9.11 \times 10^{-31} \text{ kg}$$

WORK FUNCTION & SURFACE BARRIER



DEFINITION & DEPENDENCE

- The work function, ϕ_0 , is the minimum additional energy required to remove an electron from the metal surface to a point in the vacuum just outside.
- ϕ_0 depends on the metal, surface condition, and the presence of contamination.

UNITS

The work function has units of energy: joule (J) or electron-volt (eV).

$$\begin{aligned} 1 \text{ eV} &= (1.602176634 \times 10^{-19} \text{ C})(1 \text{ V}) \\ &= 1.602176634 \times 10^{-19} \text{ J} \end{aligned}$$

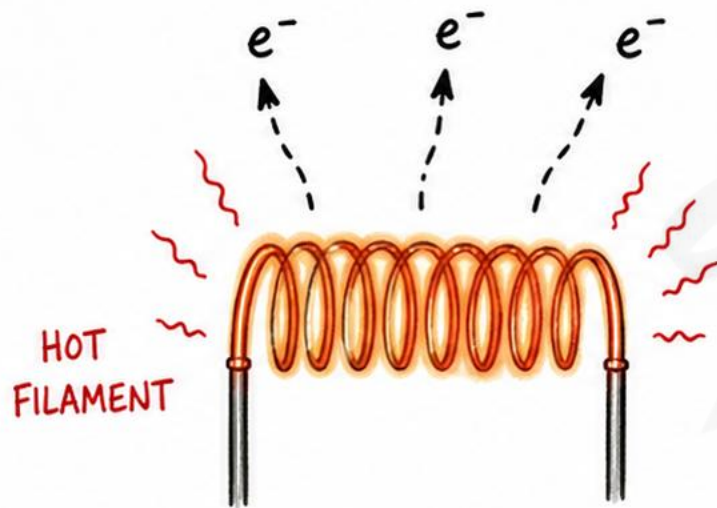
ELECTRON ENERGY NUANCE

- Conduction electrons in a metal have an energy distribution (not all the same energy).
- More energetic occupied electrons are closer to the vacuum level and therefore require less additional energy to escape. Thus, ϕ_0 is the least additional energy required for an electron to escape.

THREE MODES OF ELECTRON EMISSION

1. THERMIONIC EMISSION:

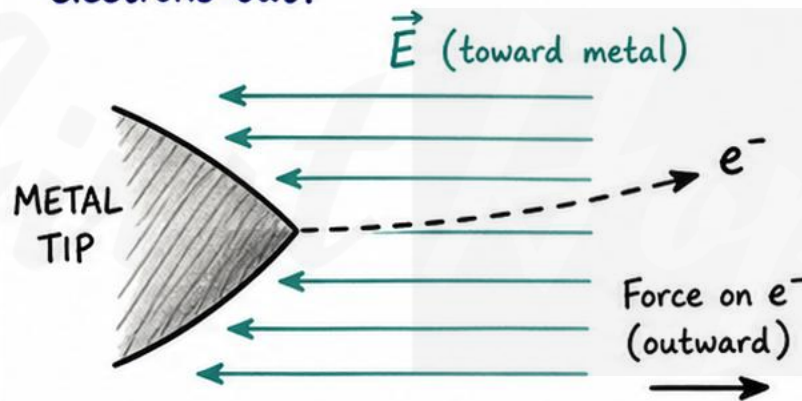
Heating supplies thermal energy.



Condition: supplied energy (thermal) is sufficient to overcome ϕ_0 .

2. FIELD EMISSION:

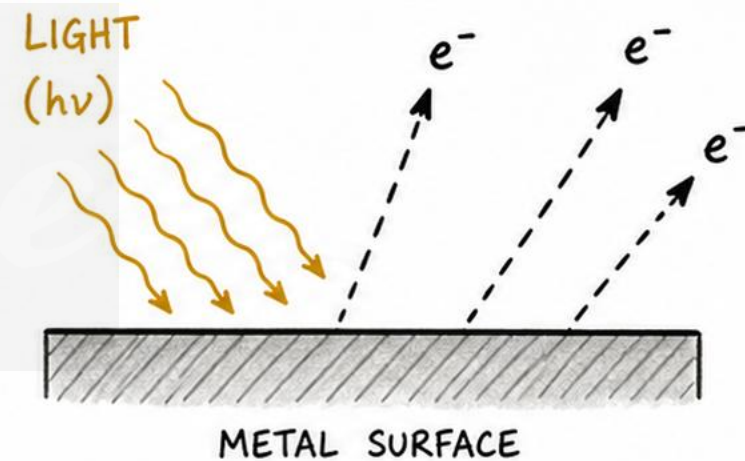
An extremely strong external electric field, of order 10^8 V m^{-1} , narrows the surface barrier and pulls/tunnels electrons out.



Electrons tunnel through the narrowed barrier due to the strong field.

3. PHOTOELECTRIC EMISSION:

Light of suitable frequency supplies energy in photons and photoelectrons leave the surface.



ENERGY SOURCE:

HEAT

STRONG ELECTRIC FIELD
($\sim 10^8 \text{ V m}^{-1}$)

RADIATION (LIGHT)
(PHOTONS, $h\nu$)

EMITTED PARTICLES:

ELECTRONS (e^-)

ELECTRONS (e^-)

ELECTRONS (e^-)

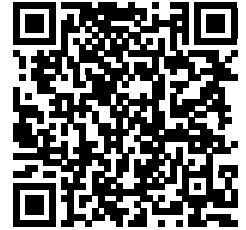


FREE PREVIEW

[Click here to visit our website](#)

SCHOOL NOTES & NCERT SOLUTIONS

Complete notes and
NCERT solutions are
available on
FirstHope app only.



[Scan or click here](#)

Click here to get the app



Available on Google Play

JOIN THE FIRSTHOPE COMMUNITY

Join our Telegram channel

Click here to join Telegram



[Scan or click here](#)

@FirstHope_CBSE_Notes

Instagram

@firsthope.school

[Click here to follow >](#)

YouTube channel

@firsthope.school

[Click here to watch >](#)

FirstHope website

firsthope.co.in

[Click here to visit our website >](#)

CBSE / Class 9 / Class 10 / Class 11 / Class 12

Preview notes and NCERT solutions. Full PDFs in the FirstHope app.