

22.3 Wave-particle duality

Name: _____ Class: _____ Date: _____

Total: 27 marks

KEY WORDS de broglie wavelength 德布罗意波长 • wave-particle duality 波粒二象性
• diffraction 衍射 • electron diffraction 电子衍射 • interference 干涉

Objective

Build the skills to answer exam questions on **wave-particle duality** and the de Broglie wavelength.

You must be able to:

- state the evidence for the **wave** and **particle** natures
- use the **de Broglie wavelength** $\lambda = h/p$
- describe **electron diffraction**

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Wave-particle duality

- particle** nature of light: the **photoelectric effect**;
- wave** nature of light: **interference** and **diffraction**.

So light has both — **wave-particle duality**. De Broglie said moving **particles** also have a wavelength:

$$\lambda = \frac{h}{p} = \frac{h}{mv}.$$

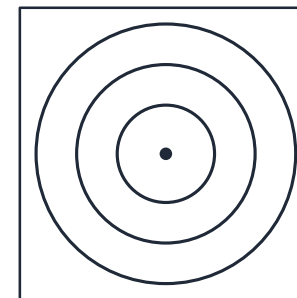
Usually you are given the **speed**: find the momentum $p = mv$ first, then $\lambda = h/p$.

Worked example. An electron ($m = 9.1 \times 10^{-31}$ kg) moves at 4.9×10^7 m s⁻¹:

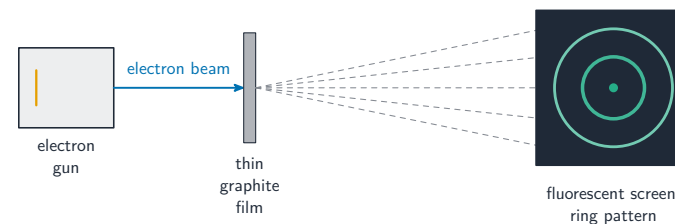
$$p = mv = 4.5 \times 10^{-23} \text{ kg m s}^{-1}, \text{ so } \lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{4.5 \times 10^{-23}} = 1.5 \times 10^{-11} \text{ m}.$$

■ Electron diffraction

Electrons fired at a thin crystal produce **diffraction rings** — only waves diffract, so this shows the **wave nature of particles**:



diffraction rings



Electron diffraction shows wave behaviour

2 Practice

Now apply the methods above.

2.1 State **one** phenomenon that is evidence for the **particle** nature of light. [1]

2.2 State **one** phenomenon that is evidence for the **wave** nature of light. [1]

2.3 Write the **de Broglie** equation. [1]

2.4 State what **electron diffraction** demonstrates. [1]

3 Exam-style questions

3.1 The de Broglie wavelength of a particle is: [1]

- | | |
|---|---|
| A | B |
| C | D |
- A** hf
B h/p
C E/c
D hc

3.2 Calculate the de Broglie wavelength of an electron with momentum $4.5 \times 10^{-23} \text{ kg m s}^{-1}$. [2]

3.3 Describe the **evidence** that electron diffraction provides for the **wave nature** of particles. [3]

3.4 Explain what is meant by **wave–particle duality**. [2]

3.5 Calculate the de Broglie wavelength of an electron moving at $4.9 \times 10^7 \text{ m s}^{-1}$. ($m_e = 9.1 \times 10^{-31} \text{ kg}$.) [3]

3.6 In an electron diffraction tube, electrons are accelerated through a potential difference of 4.8 kV and strike a thin graphite film. Take $h = 6.63 \times 10^{-34}$ J s, $e = 1.60 \times 10^{-19}$ C and the electron mass as 9.11×10^{-31} kg.

(a) **State** what is meant by the **de Broglie wavelength** of a particle. [2]

(b) **Determine** the speed of an electron after acceleration. [3]

(c) **Determine** its de Broglie wavelength. [2]

(d) **Explain** why a diffraction pattern is seen on the screen, and what it demonstrates about electrons. [3]

(e) The accelerating p.d. is **increased**. **State and explain** what happens to the spacing of the rings in the pattern. [2]
