

شرح ومساائل تدريبية على أمواج المادة



تم تحميل هذا الملف من موقع المناهج الإماراتية

موقع المناهج ← المناهج الإماراتية ← الصف الثاني عشر المتقدم ← فيزياء ← الفصل الأول ← ملفات متنوعة ← الملف

تاريخ إضافة الملف على موقع المناهج: 2026-10-30 17:26:34

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منهج انجليزي | ملخصات وتقارير | مذكرات وبنوك | الامتحان النهائي | للمدرس

المزيد من مادة
فيزياء:

إعداد: عبدالرحمن بدر

التواصل الاجتماعي بحسب الصف الثاني عشر المتقدم



صفحة المناهج
الإماراتية على
فيسبوك

الرياضيات

اللغة الانجليزية

اللغة العربية

التربية الاسلامية

المواد على تلغرام

المزيد من الملفات بحسب الصف الثاني عشر المتقدم والمادة فيزياء في الفصل الأول

شرح النموذج الكمي للذرة والليزر

1

أسئلة وزارية سابقة

2

شرح ومساائل محلولة حول قانون كولوم وقانون نيوتن في الجذب

3

أسئلة تدريبية على القوى الكهروستاتيكية ومبدأ التراكب

4

ملزمة atom the of Model s'Bohr شرح نموذج بور للذرة وتجربة رذرفورد

5

تحميل تطبيق المناهج للهواتف الذكية

تطبيق المناهج على Play Google (أندرويد)

تطبيق المناهج على Store App (آبل)

BA

BADR ACADEMY

LESSON 2
MATTER WAVES

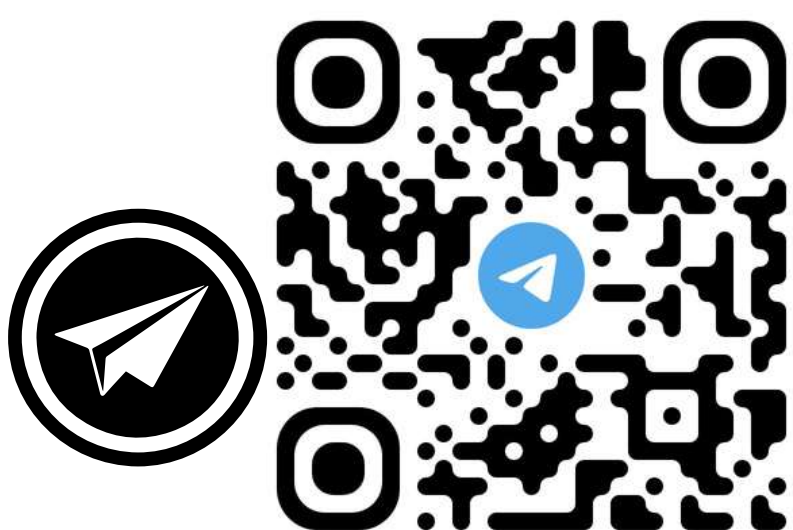
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إحجز حصصك من الواتساب
+201002507441
ABDULRAHMAN BADR
THE PHYSICS TEACHER

Abdulrahman Badr -
عبدالرحمن بدر
@abdelrahmanbadr2024
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أنا عبدالرحمن بدر، مدرس فيزياء وكيمياء ورياضيات وعلوم للمناهج
الإماراتية، أقدم شروحات مبسطة وممتعة تساعدك على فهم الدر.
more. t.me/badr_physics and 3 more links

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إعداد المهندس عبدالرحمن بدر



+201002507441



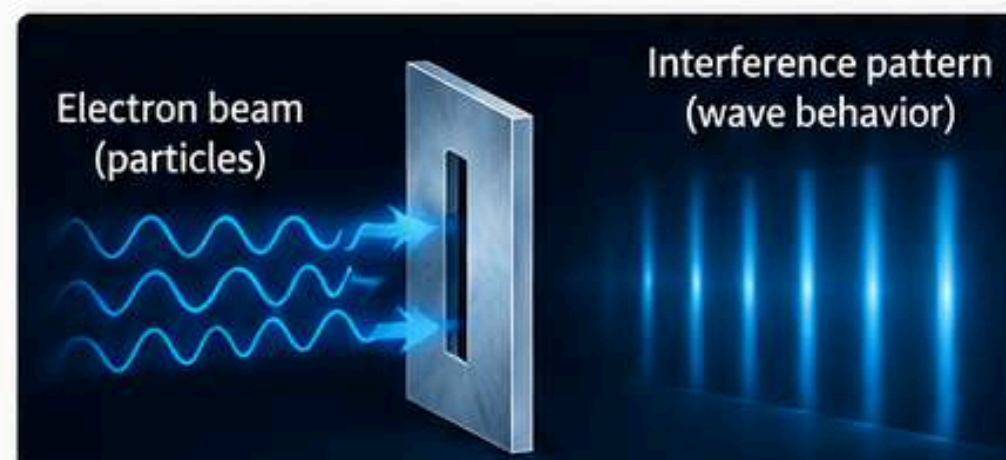
FOCUS QUESTION

How can particles be described as waves?

1 de Broglie Waves

If an electromagnetic wave can behave like a collection of particles, could a particle exhibit interference and diffraction as a wave does? In 1923, French physicist Louis de Broglie proposed that a material particle could be described by a wavelength. This proposal was a brave extension of Einstein's photon theory, and Einstein was an early supporter of de Broglie's waves.

- Every moving particle has a wave associated with it.
- This wave is called the **de Broglie wavelength**.
- Material particles can show **wave-like properties** such as **interference and diffraction**.
- In 1927, independent experiments confirmed **electron diffraction**, which provided evidence of electrons' wave-like properties.



Key Points

- Louis de Broglie (1923) proposed matter waves.
- Electron diffraction was confirmed in 1927.
- All moving particles have a wavelength.
- Everyday objects have wavelengths too small to observe.

2 De Broglie Wavelength

The de Broglie wavelength of a moving particle is equal to Planck's constant divided by the particle's momentum.

$$p = mv = \frac{h}{\lambda} \quad \Rightarrow \quad \lambda = \frac{h}{p} = \frac{h}{mv}$$

Symbols and Constants

λ	wavelength (m)
h	Planck's constant $6.63 \times 10^{-34} \text{ J} \cdot \text{s}$
m	mass of particle (kg)
v	speed of particle (m/s)
p	momentum (kg · m/s) $p = mv$

3 Example: Baseball

Objects you use every day do not exhibit wavelike properties because their wavelengths are too small to observe. For example, the wavelength of a 0.145-kg baseball moving at 38 m/s is:

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J} \cdot \text{s}}{(0.145 \text{ kg})(38 \text{ m/s})} = 1.2 \times 10^{-34} \text{ m}$$



The wavelength is extremely tiny, so no wave behavior is observed for everyday objects such as a baseball.

? Think & Predict

If the momentum of a particle increases, what happens to its de Broglie wavelength (λ)?

- ☐ Increases
- ☐ Decreases
- ☐ Stays the same



Quick Check

- 1 State the de Broglie wavelength formula for a particle in terms of its momentum and in terms of its mass and speed.

- 2 Why are the wavelengths of everyday objects too small to observe?





EXAMPLE 3 De Broglie Wavelength

An electron is accelerated by a potential difference of 75 V. What is its de Broglie wavelength?

1 ANALYZE AND SKETCH THE PROBLEM

Include the positive and the negative plates in your drawing.

Known

$$\Delta V = 75 \text{ V}$$

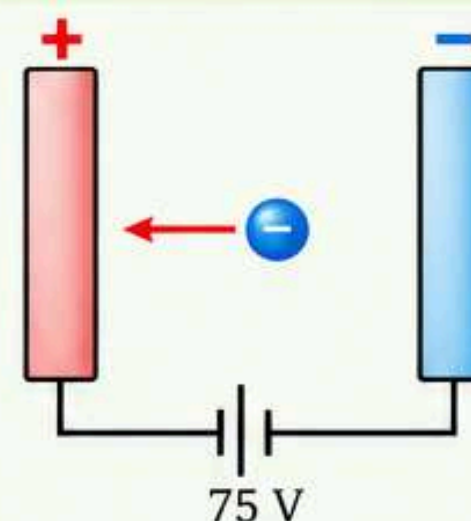
$$e = -1.602 \times 10^{-19} \text{ C}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$$

Unknown

$$\lambda = ?$$



2 SOLVE FOR THE UNKNOWN

Write relationships for the kinetic energy of the electron based on potential difference and motion, and use them to calculate the electron's velocity.

$$KE = -e\Delta V, \text{ and } KE = \frac{1}{2}mv^2$$

$$\frac{1}{2}mv^2 = -e\Delta V$$

Solve for v .

$$v = \sqrt{\frac{-2e\Delta V}{m}}$$

$$= \sqrt{\frac{-2(-1.602 \times 10^{-19} \text{ C})(75 \text{ V})}{9.11 \times 10^{-31} \text{ kg}}}$$

$$= 5.1 \times 10^6 \text{ m/s}$$

Equate the expressions for KE .

Substitute $e = -1.602 \times 10^{-19} \text{ C}$, $\Delta V = 75 \text{ V}$,
 $m_e = 9.11 \times 10^{-31} \text{ kg}$.

Use the relationship between mass, velocity, and momentum.

$$p = mv$$

$$= (9.11 \times 10^{-31} \text{ kg})(5.1 \times 10^6 \text{ m/s})$$

$$= 4.6 \times 10^{-24} \text{ kg} \cdot \text{m/s}$$

Substitute $m_e = 9.11 \times 10^{-31} \text{ kg}$, $v = 5.1 \times 10^6 \text{ m/s}$.

Use the relationship between momentum and the de Broglie wavelength.

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

$$= \frac{6.63 \times 10^{-34} \text{ J} \cdot \text{s}}{4.6 \times 10^{-24} \text{ kg} \cdot \text{m/s}}$$

$$= 1.4 \times 10^{-10} \text{ m, which equals } 0.14 \text{ nm}$$

Substitute $h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$, $p = 4.6 \times 10^{-24} \text{ kg} \cdot \text{m/s}$.

3 EVALUATE THE ANSWER

- **Are the units correct?** Dimensional analysis on the units verifies m/s for v and nm for λ .
- **Does the sign make sense?** Positive values are expected for both v and λ .
- **Are the magnitudes realistic?** The wavelength is close to 0.1 nm, which is in the X-ray region of the electromagnetic spectrum.

PRACTICE PROBLEMS

- What is the de Broglie wavelength and speed of an electron accelerated by a potential difference of 250 V?
- A 7.0-kg bowling ball rolls with a velocity of 8.5 m/s.
 - What is the de Broglie wavelength of the bowling ball?
 - Why does the bowling ball exhibit no observable wave behavior?
- What potential difference is needed to accelerate an electron so it has a 0.125-nm wavelength?
- CHALLENGE** The electron in Example Problem 3 has a de Broglie wavelength of 0.14 nm. What is the kinetic energy, in eV, of a proton with the same wavelength?

PRACTICE Problems

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What is the de Broglie wavelength and speed of an electron accelerated by a potential difference of 250 V?

Given:

$$\Delta V = 250 \text{ V}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$e = 1.602 \times 10^{-19} \text{ C}$$

$$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$$

Find:

$$v = ?$$

$$\lambda = ?$$

Solution:

1 Find the speed of the electron.

$$KE = -e\Delta V = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{-2e\Delta V}{m}}$$

$$= \sqrt{\frac{2(1.602 \times 10^{-19})(250)}{9.11 \times 10^{-31}}}$$

$$= 9.4 \times 10^6 \text{ m/s}$$

$$v = 9.4 \times 10^6 \text{ m/s}$$

2 Find the de Broglie wavelength.

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

$$= \frac{6.63 \times 10^{-34}}{(9.11 \times 10^{-31})(9.4 \times 10^6)}$$

$$= 7.7 \times 10^{-11} \text{ m}$$

$$\lambda = 7.7 \times 10^{-11} \text{ m}$$

$$= 0.077 \text{ nm}$$

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What potential difference is needed to accelerate an electron so it has a 0.125-nm wavelength?

Given:

$$\lambda = 0.125 \text{ nm}$$

$$= 0.125 \times 10^{-9} \text{ m}$$

$$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$e = 1.602 \times 10^{-19} \text{ C}$$

Find:

$$\Delta V = ?$$

Solution:

1 Find the momentum using de Broglie relation.

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{0.125 \times 10^{-9}}$$

$$= 5.30 \times 10^{-24} \text{ kg} \cdot \text{m/s}$$

2 Use kinetic energy and potential difference.

$$KE = \frac{p^2}{2m_e} = e\Delta V$$

$$\Delta V = \frac{p^2}{2m_e e}$$

$$= \frac{(5.30 \times 10^{-24})^2}{2(9.11 \times 10^{-31})(1.602 \times 10^{-19})}$$

$$= 9.65 \times 10^1 \text{ V}$$

$$\Delta V = 96.5 \text{ V}$$

$$(\approx 97 \text{ V})$$

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A 7.0-kg bowling ball rolls with a velocity of 8.5 m/s.

- What is the de Broglie wavelength of the bowling ball?
- Why does the bowling ball exhibit no observable wave behavior?

Given:

$$m = 7.0 \text{ kg}$$

$$v = 8.5 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$$

Find:

- $\lambda = ?$
- Explanation

Solution:

- Find the de Broglie wavelength.

$$\begin{aligned} \lambda &= \frac{h}{mv} \\ &= \frac{6.63 \times 10^{-34}}{(7.0)(8.5)} \\ &= 1.1 \times 10^{-35} \text{ m} \end{aligned}$$

$$\lambda = 1.1 \times 10^{-35} \text{ m}$$

(extremely small)

- Explain why there is no observable wave behavior.

The wavelength is extremely small ($\sim 10^{-35} \text{ m}$), which is far too small to be observed. Therefore, a bowling ball does not exhibit observable wave behavior.

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CHALLENGE The electron in Example Problem 3 has a de Broglie wavelength of 0.14 nm. What is the kinetic energy, in eV, of a proton with the same wavelength?

Given:

$$\lambda = 0.14 \text{ nm}$$

$$= 0.14 \times 10^{-9} \text{ m}$$

$$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$$

$$m_p = 1.67 \times 10^{-27} \text{ kg}$$

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

Find:

$$K = ? \text{ (in eV)}$$

Solution:

- Find the momentum.

$$\begin{aligned} p &= \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{0.14 \times 10^{-9}} \\ &= 4.74 \times 10^{-24} \text{ kg} \cdot \text{m/s} \end{aligned}$$

- Find the kinetic energy of the proton.

$$\begin{aligned} K &= \frac{p^2}{2m_p} = \frac{(4.74 \times 10^{-24})^2}{2(1.67 \times 10^{-27})} \\ &= 6.72 \times 10^{-21} \text{ J} \end{aligned}$$

- Convert to electron volts.

$$K = \frac{6.72 \times 10^{-21}}{1.602 \times 10^{-19}} = 4.19 \times 10^{-2} \text{ eV}$$

$$K = 0.042 \text{ eV}$$

($\approx 0.042 \text{ eV}$)

Success is liking yourself, liking what you do, and liking how you do it.

- Maya Angelou

3.1

Location and Momentum



De Broglie's theory of particles' wavelike properties led to a fundamental change in our understanding of atomic-sized objects.

In everyday experience, it is logical to think that you can measure any property to any desired level of precision.

For example, imagine measuring a ball's position during free fall. You might first try using a meterstick and a stopwatch to make the measurements. If you desire more precise measurements, you might use a video camera and a calculator or a computer. You can imagine using more and more sophisticated equipment to achieve ever greater precision. In fact, classical physics sets no limit on a measurement's precision.

Types of Measuring Tools



de Broglie's revolutionary theory of matter waves forced physicists to redefine the limits of measurement.

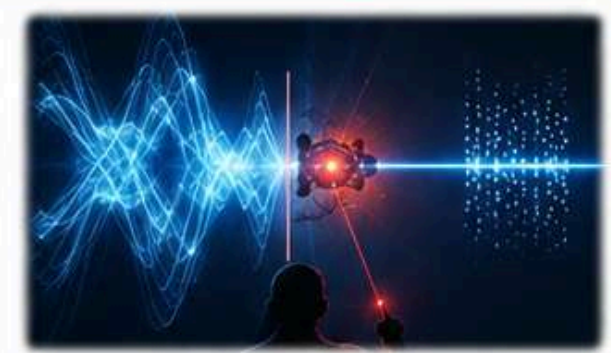
3.2

Heisenberg Uncertainty Principle



Consider measuring the location of an atomic or subatomic scale particle by shining light on it and then collecting the reflected light in a measuring device.

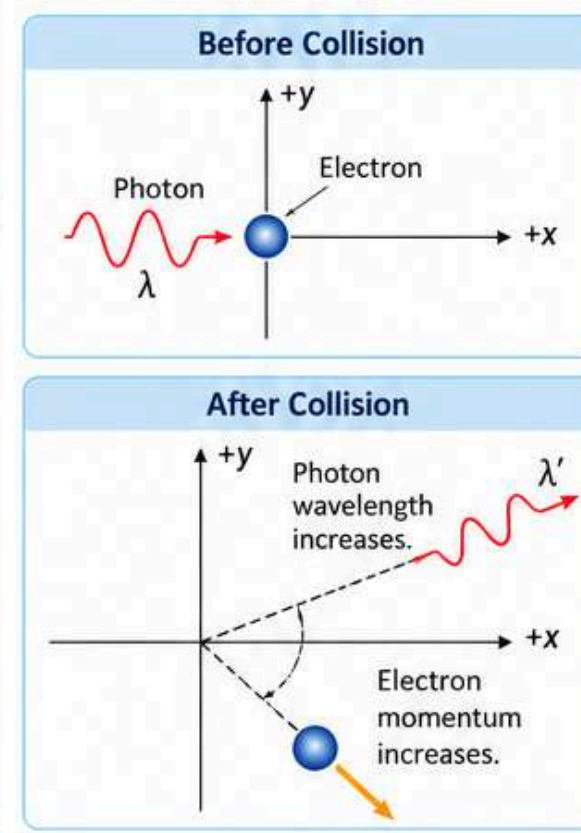
- Because of diffraction, the reflected light you use to detect the particle spreads out and makes it impossible to locate the particle exactly.
- If more precise measurements are needed, you can use shorter-wavelength radiation, which decreases diffraction and decreases the uncertainty in the particle's location.



As a result of the Compton effect, however, when short wavelength, high-energy radiation strikes a particle, the particle's momentum is changed.

Therefore, the act of measuring the location of a particle has the effect of changing the particle's momentum.

The more precise the determination of a particle's location, the greater the uncertainty is in its momentum. Similarly, if the momentum of the particle is precisely known, the position of the particle becomes less certain.



This situation is summarized by the **Heisenberg uncertainty principle**, which states there is a limit to how precisely a particle's position and momentum can simultaneously be measured.

This principle, named for German physicist Werner Heisenberg, is the result of light and matter's dual wavelike and particle-like properties.

Even though the effects of the limit are only noticeable when measuring atomic-scale particles, Heisenberg's work led to a fundamental change in our understanding of the world.

While the classical theories of Newton and Maxwell are successful models of everyday objects, quantum theory and its models of the dual nature of light and matter are required to accurately describe objects on the atomic scale.

Heisenberg's Uncertainty Principle

"We cannot precisely know both the position and momentum of a particle it is moving at the same time."

Werner Heisenberg

POSITION



MOMENTUM



$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

The more we know about where a particle is, the less we know about how fast it is moving, and vice versa.

29 Waves

Using De Broglie's theory, you can calculate the wavelength of any moving particle. Explain why the wave nature of everyday objects is not obvious.

Answer

The de Broglie wavelength of a moving particle is given by

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

For everyday (macroscopic) objects, the mass is very large, so the momentum $p = mv$ is very large, which makes the de Broglie wavelength λ **extremely small** (typically much less than atomic sizes). Such a tiny wavelength is not observable in everyday life, so the wave nature of everyday objects is not obvious.

30 Wavelength

What is the de Broglie wavelength of an alpha particle (helium nucleus) with mass 6.6×10^{-27} kg and speed 120 m/s?

Answer

The de Broglie wavelength is

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

Substitute the values:

$$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$$

$$m = 6.6 \times 10^{-27} \text{ kg}$$

$$v = 120 \text{ m/s}$$

$$\lambda = \frac{6.63 \times 10^{-34}}{(6.6 \times 10^{-27})(120)}$$

$$\lambda = \frac{6.63 \times 10^{-34}}{7.92 \times 10^{-25}}$$

$$\lambda \approx 8.4 \times 10^{-10} \text{ m} = 0.84 \text{ nm}$$

31 de Broglie Wavelength

What is the de Broglie wavelength of an electron accelerated through a potential difference of 125 V?

Answer

First, find the electron's speed from its kinetic energy:

$$K = eV = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2eV}{m}}$$

$$v = \sqrt{\frac{2(1.60 \times 10^{-19})(125)}{9.11 \times 10^{-31}}}$$

$$v \approx 6.63 \times 10^6 \text{ m/s}$$

Then use the de Broglie relation:

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

$$\lambda = \frac{6.63 \times 10^{-34}}{(9.11 \times 10^{-31})(6.63 \times 10^6)}$$

$$\lambda \approx 1.1 \times 10^{-10} \text{ m} = 0.11 \text{ nm}$$

32 Critical Thinking

How does the Heisenberg uncertainty principle explain double slit, interference pattern even if photons or atoms pass through the slits one at a time.

Answer

The Heisenberg uncertainty principle states that you **cannot simultaneously know the precise position and momentum** of a particle.

Thus, if you know the precise position of a photon or an atom as it passes through the slit, **you cannot know its precise momentum**.

Because of the unknown momentum, you **cannot be sure which of the slits the beam passed through**, resulting in the distribution of photons or atoms seen in the interference pattern.

Final Exam Practice — de Broglie Wavelength & Momentum

1

An alpha particle (helium nucleus) has a mass of 6.6×10^{-27} kg and is moving at a speed of 120 m/s. What is this alpha particle's de Broglie wavelength?

تبلغ كتلة جسم ألفا (نواة الهيليوم) 6.6×10^{-27} kg ويتحرك بسرعة 120 m/s. ما طول موجة دي برولي المصاحبة له؟

Solution

The de Broglie wavelength is

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

Substitute the values:

$$\lambda = \frac{6.63 \times 10^{-34}}{6.6 \times 10^{-27} \times 120} = 8.37 \times 10^{-10} \text{ m}$$

$$\lambda = 8.37 \times 10^{-10} \text{ m} = 0.837 \text{ nm}$$

2

An object has a de Broglie wavelength of 2.3×10^{-34} m when its velocity is 45 m/s. What is the mass of the object, in kilograms?

يبلغ طول موجة دي برولي لجسم ما 2.3×10^{-34} m عندما تكون سرعته 45 m/s. ما كتلة الجسم بالكيلوجرام؟

Solution

From $\lambda = \frac{h}{mv}$, the mass is

$$m = \frac{h}{\lambda v}$$

Substitute the values:

$$m = \frac{6.63 \times 10^{-34}}{2.3 \times 10^{-34} \times 45} = 0.064 \text{ kg}$$

$$m = 0.064 \text{ kg}$$

3

A hydrogen atom moves at speed v and has a de Broglie wavelength λ . Given that a helium atom has four times the mass of a hydrogen atom, what is the de Broglie wavelength of the helium atom if it moves at the same speed?

تتحرك ذرة هيدروجين بسرعة v وبطول موجي λ . إذا كانت كتلة ذرة الهيليوم أربعة أضعاف كتلة ذرة الهيدروجين، فما طول موجة دي برولي لذرة الهيليوم إذا تحركت بنفس السرعة؟

(A) $\frac{\lambda}{4}$

(B) λ

(C) 2λ

(D) 4λ

Solution

The de Broglie wavelength is

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

At the same speed, the wavelength is inversely proportional to mass. Since $m_{\text{He}} = 4m_{\text{H}}$,

$$\lambda_{\text{He}} = \frac{h}{4m_{\text{H}}v} = \frac{1}{4} \left(\frac{h}{m_{\text{H}}v} \right) = \frac{1}{4} \lambda_{\text{H}} = \frac{\lambda}{4}$$

$$\lambda_{\text{He}} = \frac{\lambda}{4}$$

4

Two photons, the first with a wavelength of λ and the second with a wavelength of 3λ . Which of the following is a correct relationship for the momentum of the two photons?

فوتونان، الأول طول موجته λ والثاني طول موجته 3λ . أي علاقة صحيحة لكمية حركة الفوتونين؟

(A) $P_1 = 9P_2$

(B) $P_1 = P_2$

(C) $P_1 = \frac{1}{3} P_2$

(D) $P_1 = 3P_2$

Solution

The momentum of a photon is

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

For the second photon, $\lambda_2 = 3\lambda_1$, so

$$p_2 = \frac{h}{3\lambda_1} = \frac{1}{3} \left(\frac{h}{\lambda_1} \right) = \frac{1}{3} p_1$$

Therefore,

$$P_1 = 3P_2$$

5

An electron and a proton move at the same speed (v). Which of the following is a correct relationship for the de Broglie wavelength?

الإلكترون والبروتون يتحركان بسرعة متساوية (v)، أي العلاقات الآتية صحيحة لطول موجة دي برولي؟

(A) $\lambda_p = 2\lambda_e$

(B) $\lambda_p < \lambda_e$

(C) $\lambda_p > \lambda_e$

(D) $\lambda_p = \lambda_e$

Solution

The de Broglie wavelength is

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

At the same speed, the wavelength is inversely proportional to mass. Since the proton's mass is much greater than the electron's mass ($m_p > m_e$),

$$\lambda_p < \lambda_e$$

6 Ranking Task

Rank the following particles according to their de Broglie wavelengths, from greatest to least. Specifically indicate any ties.

A an electron with a speed of 300 m/s

$$\lambda = \frac{h}{mv} \quad \lambda = \frac{6.63 \times 10^{-34}}{(9.11 \times 10^{-31})(300)} \quad \lambda_A = 2.42 \times 10^{-6} \text{m}$$

B an electron with a speed of 500 m/s

$$\lambda = \frac{h}{mv} \quad \lambda = \frac{6.63 \times 10^{-34}}{(9.11 \times 10^{-31})(500)} \quad \lambda_B = 1.45 \times 10^{-6} \text{m}$$

C a proton with a speed of 3 m/s

$$\lambda = \frac{h}{mv} \quad \lambda = \frac{6.63 \times 10^{-34}}{(1.67 \times 10^{-27})(3)} \quad \lambda_C = 0.132 \times 10^{-6} \text{m}$$

D a proton with a speed of 500 m/s

$$\lambda = \frac{h}{mv} \quad \lambda = \frac{6.63 \times 10^{-34}}{(1.67 \times 10^{-27})(500)} \quad \lambda_D = 7.94 \times 10^{-10} \text{m}$$

Ranking (greatest to least)

A > B > C > D

No ties.

7 Extra Questions

13. The kinetic energy of a hydrogen atom's electron is **13.65 eV**.

a Find the velocity of the electron.

$$K.E. = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2K.E.}{m}}$$

$$v = \sqrt{\frac{2(13.65)(1.6 \times 10^{-19})}{9.11 \times 10^{-31}}}$$

$$v = 2.19 \times 10^6 \text{ m/s}$$

b Calculate the electron's de Broglie wavelength.

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

$$\lambda = \frac{6.63 \times 10^{-34}}{(9.11 \times 10^{-31})(2.19 \times 10^6)}$$

$$\lambda = 0.332 \text{ nm}$$

c Given that a hydrogen atom's radius is **0.519 nm**, calculate the circumference of a hydrogen atom and compare it with the de Broglie wavelength for the atom's electron.

$$C = 2\pi r$$

$$C = 2\pi(0.519) = 3.26 \text{ nm}$$

The circumference is approximately equal to ten complete wavelengths.

