

QUANTUM PHYSICS II

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by **The Physics Cafe**



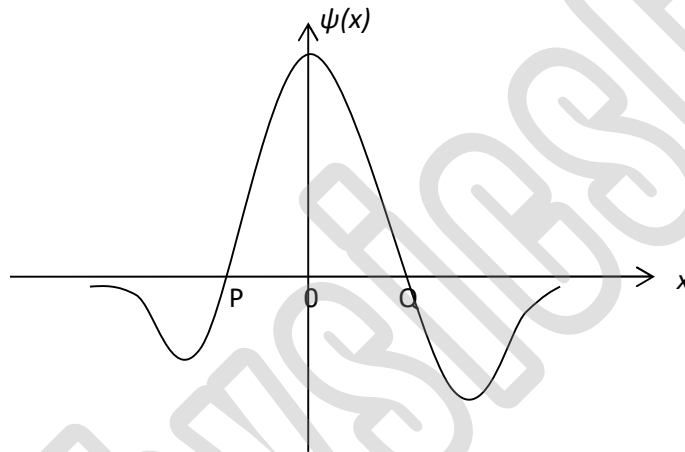
- 1 Suppose *Fuzzy*, a quantum-mechanical duck of mass 2.00 kg, lives in a world in which h , the Planck constant, is 2π J s.

Fuzzy is initially known to be within a pond 1.00 m wide.

What is the minimum uncertainty in the component of his velocity parallel to the width of the pond?

- A 0.250 m s⁻¹ B 1.00 m s⁻¹ C 2.50 m s⁻¹ D 3.14 m s⁻¹

- 2 The figure below shows the wave function $\psi(x)$ of an electron.



Which of the following statements is correct?

- A The probability of locating the electron between positions P and Q is $\int_P^Q |\psi(x)| dx$.
- B $|\psi(x)|^2$ is the probability of locating the electron within a given region.
- C There is greater probability of locating the electron on the left of the vertical axis.
- D The probability of locating the electron at $x = 0$ is the highest.

3 An electron is incident on a rectangular potential barrier with a kinetic energy of 2.0 eV. The barrier height is 6.0 eV and its width is $d = 1.0 \times 10^{-10}$ m. If the width of the barrier is reduced to d' and the transmission coefficient is doubled, the ratio $\frac{d'}{d}$ is

- A** 0.50 **B** 0.66 **C** 0.72 **D** 2.0

4 Which of the following statements about the Heisenberg Uncertainty Principle is true?

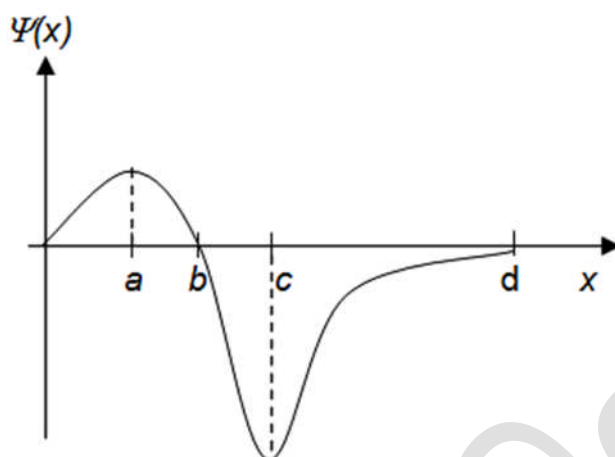
- A** This principle is not experimentally verified.
- B** This principle can only be applied to quantum particles.
- C** This principle states that if we were to improve our instrument's precision, both the positions and the momentum measurements can be improved simultaneously.
- D** This principle states that no matter how we were to improve our measurement techniques, there will always be uncertainties about the concepts of length, momentum, energy and time measurements.

5 A sodium atom stays at one of its excited states for an average of 1.6×10^{-8} s before it makes a transition down to ground state, emitting a photon of energy with wavelength 589 nm.

An estimate of the wavelength spread of the corresponding spectra line is

- A** 2.1×10^{-8} m
- B** 0.98×10^{-8} m
- C** 5.8×10^{-15} m
- D** 9.7×10^{-18} m

6 A figure shows how the wave function of a particle varies with position.

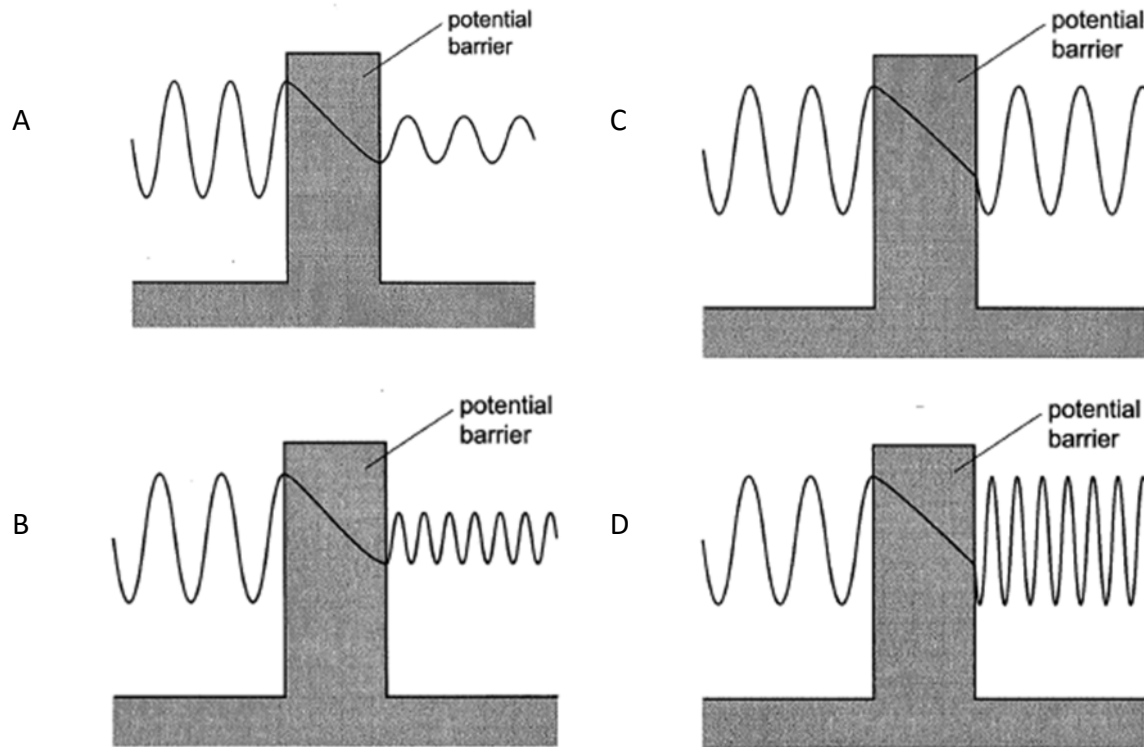


At which position is the particle most likely to be found?

- A $x = a$ B $x = b$ C $x = c$ D $x = d$

- 7 An electron of energy E is incident on the left-hand side of a potential barrier of energy U . The energy U is greater than E .

Which diagram represents the wave function of the electron to the right of the barrier?



- 8 In a simple model for a radioactive nucleus, an alpha particle ($m = 6.64 \times 10^{-27}$ kg) is trapped by a square barrier that has width 2.0 fm and height 30.0 MeV. What is the tunnelling probability, if the proportionality constant is 1.0, when the alpha particle encounters the barrier if its kinetic energy is 1.0 MeV below the top of the barrier?

- A 0.0147 B 0.0174 C 0.147 D 0.174

- 9 An excited atom gives up its excess energy by spontaneously emitting a photon. The average period that elapses between the excitation of an atom and the time it radiates is 1.0×10^{-8} s. What is the minimum uncertainty in the frequency of the emitted photon?
- A 8.0×10^{-10} Hz
B 1.6×10^{-9} Hz
C 8.0×10^6 Hz
D 16×10^6 Hz

- 10 The probing tip of a Scanning Tunnelling Microscope is placed at a height x above a metal surface and the potential difference between the tip and surface remains constant. The probability that an electron will tunnel through the gap between the tip and the surface is 8.5×10^{-15} .

What is the probability of the same electron tunnelling through the barrier when the height of the gap is increased to $1.5x$?

- A 4.2×10^{-10} B 1.9×10^{-15} C 5.7×10^{-15} D 7.8×10^{-22}

- 11 Why must the wave function of a particle be normalisable?
- A The particle's charge must be conserved.
B The particle's momentum must be conserved.
C The particle must be somewhere in the universe.
D The particle cannot be in two places at the same time.

12 A particle of mass m has kinetic energy E . Which of the following gives the de Broglie wavelength of the particle?

- A** $h\sqrt{2mE}$ **B** $\sqrt{2mE}/h$ **C** h/\sqrt{mE} **D** $h/\sqrt{2mE}$

13 A electron which undergoes spontaneous emission releases a photon in a time duration of 1.0×10^{-8} s. Find the uncertainty in the momentum of the photon emitted.

- A** 3.8×10^{-29} Ns **B** 9.8×10^{-33} Ns **C** 1.8×10^{-35} Ns **D** 4.8×10^{-65} Ns

- 14 According to the de Broglie hypothesis, matter waves are associated with
- A electrons only
 - B charged particles only
 - C neutral particles only
 - D all particles
- 15 What is the potential difference through which the electron must be accelerated from rest for it to have a wavelength of 2.4×10^{-10} m?
- A 9.48 V B 26.2 V C 52.4 V D 9.48×10^{26} V

QUANTUM PHYSICS II WORKED SOLUTIONS

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1 Ans: **A**
Apply $\Delta p \Delta x \geq h/4\pi$

2 Ans: **D**
Know the idea behind finding the probability of locating a particle with its wave function

3 Ans: **B**
Find k and apply $T \propto e^{-2kd}$
 $\frac{T'}{T} = e^{-2k(d'-d)}$
 $\ln\left(\frac{T'}{T}\right) = -2k(d'-d)$

4 Ans: **D**

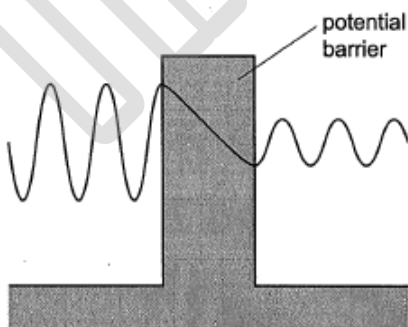
Option **A**: There are phenomena that could be explained by the HUP (i.e diffraction of photons through a slit).
Option **B**: This principle applies to all particles, not just quantum particles.
Option **C**: We can only improve the measurements of one of the quantities rather than both.
Option **D**: True.

5 Ans: **C**
 $\Delta E \Delta t \geq \frac{h}{4\pi} \rightarrow \min \Delta E = \frac{h}{4\pi \Delta t}$
 $E = \frac{hc}{\lambda} \rightarrow \frac{\Delta E}{E} = \frac{\Delta \lambda}{\lambda} \rightarrow \Delta \lambda = \frac{\lambda \Delta E}{E} = \frac{\lambda \left(\frac{h}{4\pi \Delta t} \right)}{\frac{hc}{\lambda}} = \frac{\lambda^2}{c(4\pi \Delta t)} = \frac{(589 \times 10^{-9})^2}{(3 \times 10^8)(4\pi)(1.6 \times 10^{-8})}$
 $= 5.8 \times 10^{-15} \text{ m}$

6 Ans: **C**

Highest probability density at c due to highest amplitude of wave function, Ψ where the square of the amplitude of wave function $|\Psi|^2$ gives the probability of finding the electron at a point. (No mathematical treatment is required.)

7 Ans: **A**
On RHS , wavelength unchanged, but diminished amplitude



8 Ans: **D**

Tunnelling probability, $T \propto e^{-2kd}$

$$k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}} = \sqrt{\frac{8\pi^2 (6.64 \times 10^{-27})(1.0 \times 10^6)(1.6 \times 10^{-19})}{(6.63 \times 10^{-34})^2}} = 4.37 \times 10^{14} \text{ m}^{-1}$$

Therefore, for constant of proportionality of 1.0,

$$T = e^{-2kd} = e^{-2(4.37 \times 10^{14})(2.0 \times 10^{-15})} = 0.174$$

9 Ans: **C**

$$\Delta E \Delta t \geq \frac{\hbar}{2}$$

$$\Delta(hf) \Delta t \geq \frac{h}{4\pi}$$

$$\therefore \Delta f = 7.957 \times 10^6 \text{ Hz} \approx 8.0 \times 10^6 \text{ Hz}$$

10 Ans: **D**

$$T = e^{-2kd}$$

$$T = e^{-2kx}$$

$$kx = \frac{\ln(8.5 \times 10^{-15})}{-2}$$

$$T' = e^{-2k(1.5x)}$$

$$T' = 7.8366 \times 10^{-22}$$

11 Ans: **C**

If the body is moving in 1-D along the x-axis, the sum of the probabilities over all values of x must be equal to 1. (ANSWER)

12 Ans: **D**

13 Ans: **C**

14 Ans: **D**

The de Broglie hypothesis is a fundamental principle exhibited by both radiation and matter. The de Broglie hypothesis can 'predict' wavelengths for all particles.

15 Ans: **B**

Using the conservation of energy,

Gain of KE of electron = Loss of EPE of electron

$$\frac{p^2}{2m} = q_e V$$

$$\frac{(h/\lambda)^2}{2m} = q_e V$$

$$V = \frac{(h/\lambda)^2}{2mq_e}$$

$$V = \frac{(6.63 \times 10^{-34})^2}{2(2.4 \times 10^{-10})^2(9.11 \times 10^{-31})(1.6 \times 10^{-19})} = 26.2 \text{ V}$$

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