National Testing Agency

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Introduction to Quantum Physics and its Applications

Group Number :	1
Group Id :	89951413
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Introduction to Quantum Physics and its Applications

Section Id :	89951413
Section Number :	1
Section type :	Online
Mandatory or Optional :	Mandatory

Number of Questions : 15
Number of Questions to be attempted : 15
Section Marks : 90
Display Number Panel : Yes
Group All Questions : Yes
Mark As Answered Required? : Yes
Sub-Section Number : 1
Sub-Section Id : 89951422
Question Shuffling Allowed : Yes

Question Number : 1 Question Id : 8995141011 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

The energy density u of radiation in a blackbody, in thermal equilibrium at temperature T, is also a function of the frequency of radiation ν. The function $u(\nu, T) \rightarrow 0$ for both $\nu \rightarrow 0$ and $\nu \rightarrow \infty$. It attains its maximum value for some ν_{max}. The approximate value of ν_{max} is (k and h are Boltzmann and Planck's constants respectively)

(A) kT/h

(B) 2kT/h

(C) 3kT/h

(D) 4kT/h

Options :
8995144021. 1
8995144022. 2
8995144023. 3
8995144024. 4

Question Number : 2 Question Id : 8995141012 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question

Mandatory : No Single Line Question Option : No Option Orientation : Vertical
Correct Marks : 6 Wrong Marks : 0

A light of frequency ν is incident on a metal and a photocurrent was emitted. This photocurrent is stopped when a potential V_S (stopping potential) is applied to the metal. An experiment is performed with different values of ν and the corresponding V_S values were measured. The relation between Vs and ν is

(A) $Vs = a\nu$

(B) $Vs = a\nu - b$

(C) $Vs = a\nu^2$

(D) $Vs = a\nu^2 - b$

In the above equations, a and b are constants of appropriate dimensions.

Options :
8995144025. 1
8995144026. 2
8995144027. 3
8995144028. 4

Question Number : 3 Question Id : 8995141013 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical
Correct Marks : 6 Wrong Marks : 0

Consider a new kind of atom where the electron is in a circular orbit about a proton. If the binding energy of the n-th orbit is given by $E_n = -E_0/n$, where E_0 is a constant, the angular momentum of this orbit is given by

(A) $n^2\hbar$

(B) $n\hbar$

(C) $n^{1/2}\hbar$

(D) $n^{1/4}\hbar$

Options :

8995144029. 1

8995144030. 2

8995144031. 3

8995144032. 4

Question Number : 4 Question Id : 8995141014 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

A particle is in a state described by the wavefunction

$$\psi(x) = \frac{N}{x^2+a^2},$$

where N is the normalization constant and a is a constant with dimension of length. The uncertainty in the position coordinate of the particle is

(A) $\frac{a}{\sqrt{2}}$

(B) a

(C) $a\sqrt{2}$

(D) $2a$

Options :

8995144033. 1

8995144034. 2

8995144035. 3

8995144036. 4

Question Number : 5 Question Id : 8995141015 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

A particle of mass m is confined to a 1-dimensional region $[0, a]$, whose normalized wave function is

$$\psi(x) = \sqrt{\frac{8}{5a}}\left[1 + \cos\left(\frac{\pi x}{a}\right)\right]\sin\left(\frac{\pi x}{a}\right)$$

The average energy of the particle is

(A) $\frac{5\pi^2\hbar^2}{4ma^2}$

(B) $\frac{6\pi^2\hbar^2}{5ma^2}$

(C) $\frac{4\pi^2\hbar^2}{5ma^2}$

(D) $\frac{5\pi^2\hbar^2}{6ma^2}$

Options :

8995144037. 1

8995144038. 2

8995144039. 3

8995144040. 4

Question Number : 6 Question Id : 8995141016 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

Consider a stream of particles of mass m, each moving in the positive x −direction with kinetic energy E towards a potential jump located at $x = 0$. The potential is zero for $x \leq 0$ and $3E/4$ for $x > 0$. The fraction of particles which will be reflected back at $x = 0$ will be

(A) 1/9

(B) 1/6

(C) 1/4

(D) 1/3

Options :

8995144041. 1
8995144042. 2
8995144043. 3
8995144044. 4

Question Number : 7 Question Id : 8995141017 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

An operator $\hat{A}$, representing observable A, has two normalized eigenstates ψ_1 and ψ_2, with eigenvalues a_1 and a_2, respectively. Operator $\hat{B}$, representing observable B, has two normalized eigenstates ϕ_1 and ϕ_2, with eigenvalues b_1 and b_2, respectively. The eigenstates are related by

$$\psi_1 = (3\phi_1 + 4\phi_2)/5, \quad \psi_2 = (4\phi_1 - 3\phi_2)/5$$

After preparing the system in a general state, observable B is first measured, and the value b_1 is obtained. If A is measured immediately afterwards, the possible results for the probabilities of finding eigenvalues a_1 and a_2 are

(A) 9/25 and 16/25

(B) 16/25 and 9/25

(C) 3/5 and 4/5

(D) 4/5 and 3/5

Options :

8995144045. 1

8995144046. 2

8995144047. 3

8995144048. 4

Question Number : 8 Question Id : 8995141018 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

Consider a particle of mass m moving in a 1-dimensional potential well of width a

$$V(x) = \infty, \quad x < 0$$
$$= 0, \quad 0 \le x \le a$$
$$= V_0, \quad x > a$$

The bound state energies ($E<V_0$) of the particle in such a potential well are given by

(A) $\tan\left(\frac{a\sqrt{2mE}}{\hbar}\right) = -\frac{V_0 - E}{E}$

(B) $\tan\left(\frac{a\sqrt{2mE}}{\hbar}\right) = -\frac{E}{V_0 - E}$

(C) $\tan\left(\frac{a\sqrt{2mE}}{\hbar}\right) = -\sqrt{\frac{V_0 - E}{E}}$

(D) $\tan\left(\frac{a\sqrt{2mE}}{\hbar}\right) = -\sqrt{\frac{E}{V_0 - E}}$

Options :

8995144049. 1

8995144050. 2

8995144051. 3

8995144052. 4

Question Number : 9 Question Id : 8995141019 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

Sodium is a metal with electrical conductivity $2.17 \times 10^7\ \Omega^{-1}\text{m}^{-1}$. If sodium is kept in a field of $200\ V\text{m}^{-1}$, the drift velocity (in m/sec) of the electron will be (assume that only one conduction electron is available for each sodium atom) (Given, density of Sodium = 970 Kg m^{-3}, atomic mass of Sodium = 23 amu, charge of electron=1.6×10^{-19} Coulomb, Avogadro's number = 6.0×10^{23})

(A) 1.1

(B) 9.1

(C) 50.1

(D) 120.1

Options :

8995144053. 1

8995144054. 2

8995144055. 3

8995144056. 4

Question Number : 10 Question Id : 8995141020 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

The density of copper is 8.94 $gm\ cm^{-3}$ and its atomic weight is 63.5 per molecule, the effective mass of electron being 1.01. Assume that each atom gives one electron, calculate the average energy $< E >$ of the free electrons at 0 ^{0}K. The temperature (in Kelvin) required for the average kinetic energy of a gas molecules to posses this value of $< E >$ is

(A) 3.22×10^4

(B) 9.22×10^4

(C) 3.22×10^3

(D) 9.22×10^3

Options :

8995144057. 1

8995144058. 2

8995144059. 3

8995144060. 4

Question Number : 11 Question Id : 8995141021 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

A 3D confinement potential $V(x,y,z)$ is defined as follows:

$$V(x,y,z) = V(x) + V(y) + V(z)$$

where, for $0 < z < L$ (for all x and y)

$$V(x,y) = V(x) + V(y) = \frac{1}{2} m\omega^2 (x^2 + y^2) \quad and \quad V(z) = 0$$

and for $z \leq 0 \quad and \quad z \geq L$ (for all x and y)

$$V(x,y,z) = \infty$$

Consider $L = \pi\sqrt{\hbar/(10m\omega)}$. The degeneracy of the state with energy $E = 19\hbar\omega$ is

(A) 19

(B) 14

(C) 13

(D) 4

Options :

8995144061. 1

8995144062. 2

8995144063. 3

8995144064. 4

Question Number : 12 Question Id : 8995141022 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

Assume the energy of an electron in a band of 1-dimensional solid is given by

$$E(k) = E_0 \sin^2\left(\frac{ka}{2}\right)$$

The effective mass of the electron, when $ka = \pi/3$, is

(A) $\frac{\hbar^2}{a^2 E_0}$

(B) $\frac{2\hbar^2}{a^2 E_0}$

(C) $\frac{3\hbar^2}{a^2 E_0}$

(D) $\frac{4\hbar^2}{a^2 E_0}$

Options :

8995144065. 1

8995144066. 2

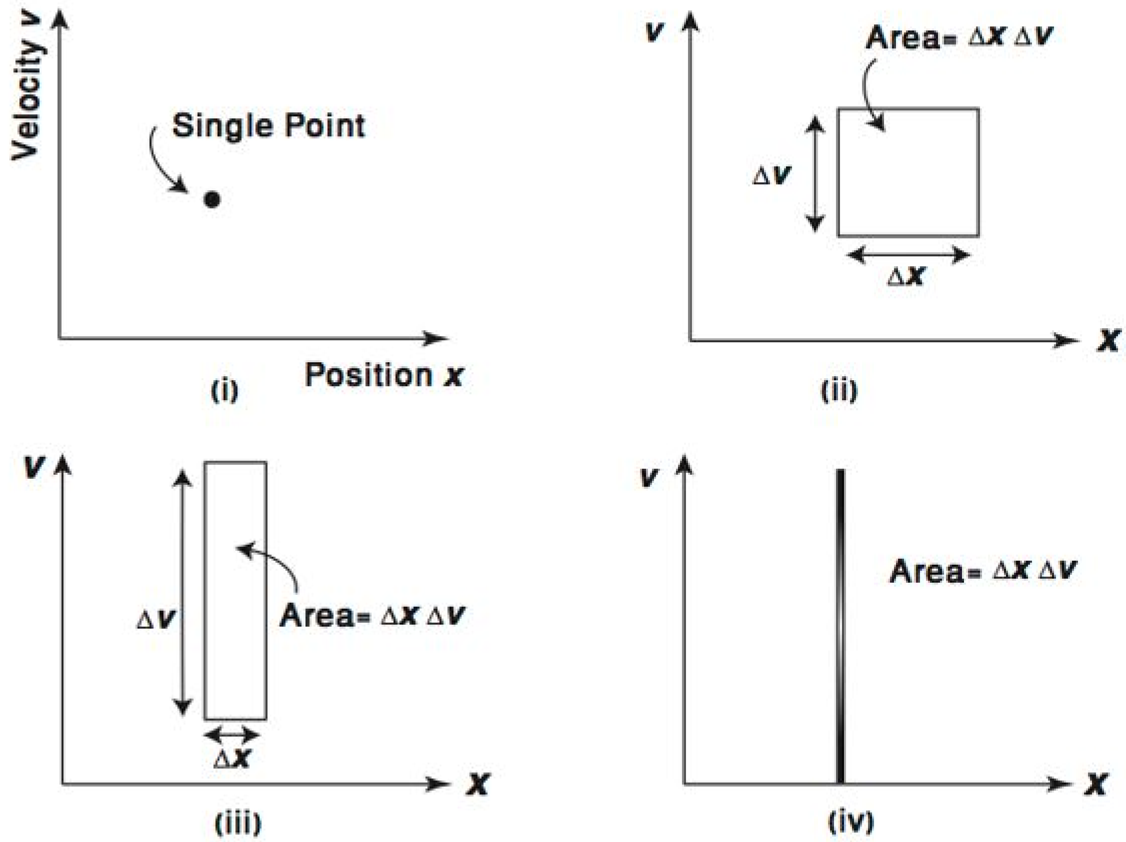
8995144067. 3

8995144068. 4

Question Number : 13 Question Id : 8995141023 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

For a particle moving in 1-dimension, the phase space is a plane with position x plotted along horizontal axis and velocity v plotted along vertical axis. Four possible phase space figures are shown below. Which one of these figures does NOT represent the motion of a free electron?



(A) (i)

(B) (ii)

(C) (iii)

(D) (iv)

Options :

8995144069. 1
8995144070. 2
8995144071. 3
8995144072. 4

Question Number : 14 Question Id : 8995141024 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical
Correct Marks : 6 Wrong Marks : 0

A one dimensional, finite potential barrier has the form

$$V(x) = 0 \quad for \; -\infty < x < 0$$

$$= V_0 \quad for \; 0 < x < L$$

$$= 0 \quad for \; L < x < \infty$$

where V_0 is a positive constant. A beam of particles with kinetic energy $0<E<V_0$ is incident on the barrier from $x = -\infty$. The probabilitity of a particle tunneling through the barrier varies with the width of the well (L) as

(A) $1/L$

(B) $1/L^2$

(C) $\exp(-\alpha L)$, where α is a constant of appropriate dimension

(D) $\exp(-\beta L^2)$, where β is a constant of appropriate dimension

Options :
8995144073. 1
8995144074. 2
8995144075. 3
8995144076. 4

Question Number : 15 Question Id : 8995141025 Question Type : MCQ Option Shuffling : No Display Question Number : Yes Is Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical

Correct Marks : 6 Wrong Marks : 0

A particle of mass m is confined to a 1-dimensional region $[0, L]$. At time t=0, its wave function is

$$\psi(x) = N\sin^3\left(\frac{\pi x}{L}\right)$$

where N is the normalization constant. The ground state energy of this particle is $E = \frac{\pi^2\hbar^2}{2mL^2}$. The expression for the wavefunction at a later time t is

(A) $\left(\frac{N}{4}\right)\left[3\sin\left(\frac{\pi x}{L}\right) - \sin\left(\frac{3\pi x}{L}\right)e^{-i\frac{8Et}{\hbar}}\right]e^{-i\frac{Et}{\hbar}}$

(B) $\left(\frac{N}{4}\right)\left[3\sin\left(\frac{\pi x}{L}\right) + \sin\left(\frac{3\pi x}{L}\right)e^{-i\frac{8Et}{\hbar}}\right]e^{-i\frac{Et}{\hbar}}$ L SEP

(C) $N\left[\sin^3\left(\frac{\pi x}{L}\right)\right]e^{-i\frac{Et}{\hbar}}$

(D) $N\left[\sin^3\left(\frac{\pi x}{L}\right)\right]e^{-i\frac{9Et}{\hbar}}$

Options :

8995144077. 1

8995144078. 2

8995144079. 3

8995144080. 4