# National Testing Agency

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| **Question Paper Name :** | Introduction to Quantum Physics<br>September 2020 Shift 1 |
| **Subject Name :** | Introduction to Quantum Physics |
| **Creation Date :** | 2020-09-15 13:26:32 |
| **Duration :** | 180 |
| **Total Marks :** | 90 |
| **Display Marks:** | Yes |
| **Share Answer Key With Delivery Engine :** | Yes |
| **Actual Answer Key :** | Yes |

## Introduction to Quantum Physics and its Applicatio

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|---|---|
| **Group Number :** | 1 |
| **Group Id :** | 89951413 |
| **Group Maximum Duration :** | 0 |
| **Group Minimum Duration :** | 120 |
| **Show Attended Group? :** | No |
| **Edit Attended Group? :** | No |
| **Break time :** | 0 |
| **Group Marks :** | 90 |
| **Is this Group for Examiner? :** | No |

## Introduction to Quantum Physics and its Applicatio

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

9/16/2020

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|---|---|
| **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 Quest 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 temperature T, is also a function of the frequency of radiation $\nu$. The functi $u(\nu, T) \to 0$ for both $\nu \to 0$ and $\nu \to \infty$. It attains its maximum value for sor $\nu_{max}$. The approximate value of $\nu_{max}$ is (k and h are Boltzmann and Planck 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 Quest

9/16/2020

**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 emitte
This photocurrent is stopped when a potential $V_S$ (stopping potential) is applie
to the metal. An experiment is performed with different values of ν and t
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 Quest
Mandatory : No Single Line Question Option : No Option Orientation : Vertical
Correct Marks : 6 Wrong Marks : 0

9/16/2020

Consider a new kind of atom where the electron is in a circular orbit about proton. If the binding energy of the $n$-th orbit is given by $E_n = -E_0/n$, wher $E_0$ 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 Quest Mandatory : No Single Line Question Option : No Option Orientation : Vertical**

**Correct Marks : 6 Wrong Marks : 0**

9/16/2020

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 o 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 Quest
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 $[0, a]$,
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)** $\frac{6\pi^2\hbar^2}{5ma^2}$ [L SEP]

**(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 Quest
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 po
$x$ −direction with kinetic energy $E$ towards a potential jump located at $x =$ (
potential is zero for $x \leq 0$ and $3E/4$ for $x > 0$. The fraction of particles
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 Quest
Mandatory : No Single Line Question Option : No Option Orientation : Vertical
Correct Marks : 6 Wrong Marks : 0

9/16/2020

An operator $\hat{A}$, representing observable A, has two normalized eigenstates ψ
and $\psi_2$, with eigenvalues $a_1$ and $a_2$, respectively. Operator $\hat{B}$, representi
observable B, has two normalized eigenstates $\phi_1$ and $\phi_2$, with eigenvalues
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, a
the value $b_1$ is obtained. If A is measured immediately afterwards, the possib
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 Quest
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 wid

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

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

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

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

9/16/2020

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

**(A)** $3.22 \times 10^4$

**(B)** $9.22 \times 10^4$

**(C)** $3.22 \times 10^3$

**(D)** $9.22 \times 10^3$

Options :
8995144057. 1
8995144058. 2
8995144059. 3
8995144060. 4

**Question Number : 11 Question Id : 8995141021 Question Type : MCQ Option Shuffling : No Display Ques**
**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 $z \leq 0$ *and* $z \geq L$ (for all $x$ and $y$)

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

Consider $L = \pi \sqrt{\hbar / (10 m\omega)}$. 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 Que
Question Mandatory : No Single Line Question Option : No Option Orientation : Vertical
Correct Marks : 6 Wrong Marks : 0

9/16/2020

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)** $\frac{2\hbar^2}{a^2 E_0}$

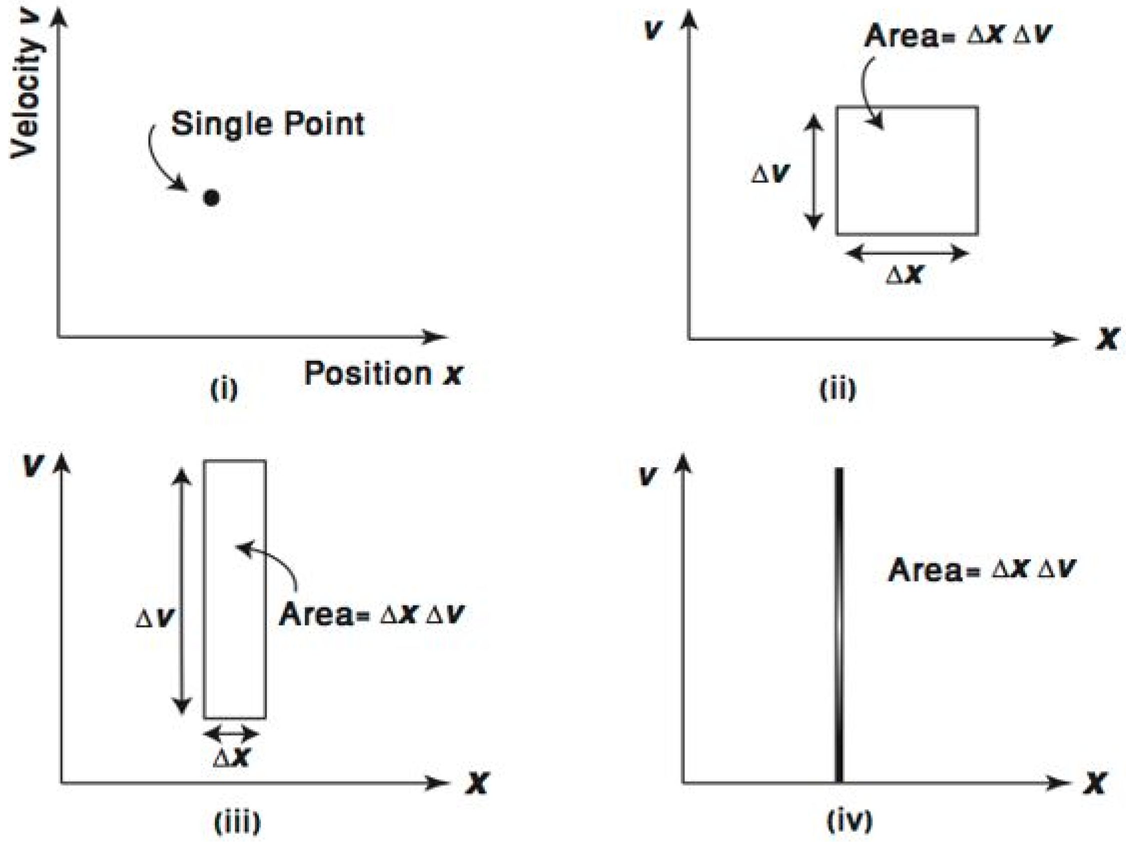
**(C)** $\frac{3\hbar^2}{a^2 E_0}$

**(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 Que
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 posi plotted along horizontal axis and velocity $v$ plotted along vertical axis. possible phase space figures are shown below. Which one of these figure 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 Que**
**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<
is incident on the barrier from $x = -\infty$. The probabilitity of a particle tunn
through the barrier varies with the width of the well $(L)$ as

**(A)** $1/L$

**(B)** $1/L^2$

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

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

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

9/16/2020

**Question Number : 15 Question Id : 8995141025 Question Type : MCQ Option Shuffling : No Display Que**
**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=
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 parti
$E = \frac{\pi^2\hbar^2}{2mL^2}$. 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