	1 A	If the electric field of a photon is represented by	1 Marks	Part-A
momentum of the photon is				
Ans: 5 Range: NA Hints: $p = h\sqrt{3^2 + 4^2} = 5h$ 1 B If the electric field of a photon is represented by $\vec{E}(in SI units) = 4i \cos[(6y + 8z) - 2t]$ then the magnitude of the momentum of the photon is				
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Hints: $p = h \sqrt{3^2 + 4^2} = 5h$ If the electric field of a photon is represented by $\overline{E}(in SI \ units) = 4^{\frac{1}{4}} \cos[(6y + 8z) - 2t]$ then the magnitude of the momentum of the photon is		Ans: 5		
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$\begin{array}{c} x\ 10^{-31} \text{kg}) \\ \text{(Write the answer correct upto two decimal places)} \\ \text{Ans: } 17.60 \\ \text{Range: } 17\ \text{to } 18 \\ K = \frac{hc}{\lambda} - \phi = 1.76 \times 10^{-19} J \rightarrow p = \sqrt{2mK} = 5.63 \times 10^{-25} \ Kg \frac{m}{s} \rightarrow B = \frac{p}{re} \\ & \rightarrow 17.6 \ \mu\text{T} \\ \end{array}$ $\begin{array}{c} \text{2C} \text{A beam of } 400 \ \text{nm light is incident on a metal with a work function } 2 \ \text{eV} \\ \text{placed in the magnetic field of magnitude 'B'. The most energetic electrons, emitted perpendicular to the field are bent in circular arcs of radius 15 cm.} \\ \text{The value of 'B' (in } \mu\text{T) is (Take } \text{hc=}1240 \ \text{nm-eV}, 1 \ \text{eV=} 1.6 \ \text{x } 10^{-19} \text{J}, \text{m}_{\text{e}}=9 \end{array}$				
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$\begin{array}{c ccccccccccccccccccccccccccccccccccc$				
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		$K = \frac{nc}{10} - \phi = 1.76 \times 10^{-19} J \rightarrow p = \sqrt{2mK} = 5.63 \times 10^{-25} Kg \xrightarrow{m} \rightarrow B = \frac{p}{100}$		
placed in the magnetic field of magnitude 'B'. The most energetic electrons, emitted perpendicular to the field are bent in circular arcs of radius 15 cm. The value of 'B' (in μ T) is (Take hc=1240 nm-eV, 1 eV= 1.6 x 10 ⁻¹⁹ J, m _e =9				
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v 10-31kg)				
x 10 · kg)		$x 10^{-31} kg$		

		I	
	(Write the answer correct upto two decimal		
	places)		
	Ans: 23.5		
	Range: 23 to 24		
	$K = \frac{hc}{\lambda} - \phi = 1.76 \times 10^{-19} J \rightarrow p = \sqrt{2mK} = 5.63 \times 10^{-25} Kg \frac{m}{s} \rightarrow B = \frac{p}{re} \rightarrow$		
	λ 3 76		
3A	23.5 μT When an electron is accelerated through a potential difference V, its	2 Marks	Part-B
JA		2 IVIAIKS	ו מונים
	de Broglie wavelength is $\lambda = \sqrt{\left(\frac{\alpha}{V}\right)}$ for non-relativistic speeds. If λ and V		
	represent numerical values in angstrom and volt respectively, then the magnitude of α is		
	(Write the answer correct up to two decimal places) (Take $h = 6.63 \times 10^{-34} \text{ J-s}$		
	and $m_e = 9 \times 10^{-31} \text{kg}$		
	Ans: 149		
	Range: 147 to 151		
	•		
	Hints: $eV = \frac{mv^2}{2} = \frac{p^2}{2m} \rightarrow p = \sqrt{(2meV)} \rightarrow \lambda = \frac{h}{p} \rightarrow \lambda = \sqrt{\frac{1.49}{V}} nm \rightarrow$		
	$\sqrt{\frac{149}{V}} A$		
3B	When an electron is accelerated through a potential difference V, its	2 Marks	Part-B
ЭБ		2 IVIAIKS	ган-Б
	de Broglie wavelength is $\lambda = \frac{\alpha}{\sqrt{V}}$ for non-relativistic speeds. If λ and V		
	represent numerical values in angstrom and volt respectively, then the		
	magnitude of α is		
	(Write the answer correct up to two decimal places) (Take $h = 6.63 \times 10^{-34} \text{ J-s}$ and $m_e = 9 \times 10^{-31} \text{ kg}$)		
	and me = 9 x10 kg)		
	Ans: 12.22		
	Range: 12 to 13		
	Hints: $eV = \frac{mv^2}{2} = \frac{p^2}{2m} \rightarrow p = \sqrt{(2meV)} \rightarrow \lambda = \frac{h}{p} \rightarrow \lambda = \sqrt{\frac{1.49}{V}} nm \rightarrow \alpha = 0$		
	Hints: $eV = \frac{1}{2} = \frac{1}{2m} \rightarrow p = \sqrt{(2meV)} \rightarrow \lambda = \frac{1}{p} \rightarrow \lambda = \sqrt{\frac{1}{V}} nm \rightarrow \alpha = \frac{1}{2} = \frac{1}{2m} nm \rightarrow \alpha = \frac{1}{$		
	12.22		
3C	When an electron is accelerated through a potential difference V, its	2 Marks	Part-B
	de Broglie wavelength is $\lambda = \frac{\alpha^2}{\sqrt{V}}$ for non-relativistic speeds. If λ and V		
	represent numerical values in angstrom and volt respectively, then the		
	magnitude of α is		
	(Write the answer correct up to two decimal places)		
	(Take $h^2 = 3m_e \text{ kg.eV.nm}^2 \text{ where } m_e = 9 \text{ x } 10^{-31} \text{ kg}$)		
	Ans: 3.5		
	Range: 3 to 4		
	Hints: $eV = \frac{mv^2}{2} = \frac{p^2}{2m} \rightarrow p = \sqrt{(2meV)} \rightarrow \lambda = \frac{h}{p} \rightarrow \lambda = \sqrt{\frac{1.49}{V}} nm \rightarrow \alpha = 0$		
	$\begin{array}{cccccccccccccccccccccccccccccccccccc$		
4A	Davisson and Germer experiment is repeated with a crystal that has the	1 Marks	Part-A
	spacing between Bragg's planes is 0.08 nm. First maximum is seen at $\theta = 60^{\circ}$		
	for a monochromatic beam of electrons. The wavelength (in nm) associated		
	with the scattered electron is		
	(Write the answer correct up to two decimal places)		
	Anc. 0.14		
	Ans: 0.14		

	Range: 0.13 to 0.15		
	Hints: $2\phi + \theta = \pi$; $\lambda = \frac{2d}{n}\sin(\phi) = \frac{2d}{n}\cos\left(\frac{\theta}{2}\right) \rightarrow \lambda = 0.138 nm$		
4B	Davisson and Germer experiment is repeated with a crystal that has the spacing between Bragg's planes is 0.06 nm. First maximum is seen at $\theta = 60^{\circ}$ for a monochromatic beam of electrons. The wavelength (in nm) associated with the scattered electron is (Write the answer correct upto two decimal places)	1 Marks	Part-A
	Ans: 0.10 Range: 0.08 to 0.12 Hints: $2\phi + \theta = \pi$; $\lambda = \frac{2d}{n}\sin(\phi) = \frac{2d}{n}\cos\left(\frac{\theta}{2}\right) \rightarrow \lambda = 0.103 \ nm$		
4C	Davisson and Germer experiment is repeated with a crystal that has the spacing between Bragg's planes is 0.1 nm. One maximum is seen at $\theta = 60^{\circ}$ for a monochromatic beam of electrons. The wavelength (in nm) associated with the scattered electron is (Write the answer correct upto two decimal places)	1 Marks	Part-A
	Ans: 0.17 Range: 0.15 to 0.19 Hints: $2\phi + \theta = \pi$; $\lambda = \frac{2d}{n}\sin(\phi) = \frac{2d}{n}\cos\left(\frac{\theta}{2}\right) \rightarrow \lambda = 0.173 \ nm$		
5A	If the expression $[\hat{x}^5, \hat{p}_x]$ is simplified in terms of \hat{x} , then the power of \hat{x} is	1 Marks	Part-A
	Ans: 4 Range: NA Hint: $[\hat{x}^n, \hat{p}_x] = i\hbar n\hat{x}^{n-1}$		
5B	If the expression $[\hat{x}^4, \hat{p}_x]$ is simplified in terms of \hat{x} , then the power of \hat{x} is	1 Marks	Part-A
	Ans: 3 Range: NA Hint: $[\hat{x}^n, \hat{p}_x] = i\hbar n\hat{x}^{n-1}$		
5C	If the expression $[\hat{x}^3, \hat{p}_x]$ is simplified in terms of \hat{x} , then the power of \hat{x} is	1 Marks	Part-A
	Ans: 2 Range: NA Hint: $[\hat{x}^n, \hat{p}_x] = i\hbar n\hat{x}^{n-1}$		
6A	A particle of mass m is confined to a one-dimensional well $0 < x < L$. At $t = 0$ its wave function is $\psi(x,0) = A \sin\left(\frac{\pi x}{L}\right)$ where A is the normalisation constant. What is the probability that the	2 Marks	Part-B
	particle is found between $L/2$ and $3L/4$ at a later time t_0 ?		
	Ans: 0.41 Range: 0.38 to 0.44		
	The normalizat ion constnat,		
	$A^2 \int_0^L \sin^2\left(\frac{\pi x}{L}\right) dx = 1 \Rightarrow A = \sqrt{\frac{2}{L}};$		
	6(a) $P = \frac{2}{L} \int_{L/2}^{3L/4} \sin^2\left(\frac{\pi x}{L}\right) dx = 0.41$		

6B	A particle of mass m is confined to a one-dimensional well $0 < x < L$. At $t =$	2 Marks	Part-B
	0 its wave function is (πx)		
	$\psi(x,0) = A\sin\left(\frac{nx}{L}\right)$		
	where A is the normalisation constant. What is the probability that the		
	particle is found between L/4 and L/2 at a later time t_0 ?		
	Ans: 0.41		
	Range: 0.38 to 0.44		
	The normalizat ion constnat,		
	$A^2 \int_0^L \sin^2\left(\frac{\pi x}{L}\right) dx = 1 \Rightarrow A = \sqrt{\frac{2}{L}};$		
	$6(b) P = \frac{2}{L} \int_{L/4}^{L/2} \sin^2\left(\frac{\pi x}{L}\right) dx = 0.41$		
6C	A particle of mass m is confined to a one-dimensional well $0 < x < L$. At $t = 0$ its wave function is	2 Marks	Part-B
	$\psi(x,0) = A \sin\left(\frac{\pi x}{I}\right)$		
	where A is the normalisation constant. What is the probability that the		
	particle is found between L/4 and 3L/4 at a later time t_0 ?		
	Ans: 0.82		
	Range: 0.78 to 0.86		
	The normalizat ion constnat,		
	$A^2 \int_0^L \sin^2\left(\frac{\pi x}{L}\right) dx = 1 \Rightarrow A = \sqrt{\frac{2}{L}};$		
	$6(c) P = \frac{2}{L} \int_{L/4}^{3L/4} \sin^2\left(\frac{\pi x}{L}\right) dx = 0.82$		
7A	An electron is confined in the ground state in a one-dimensional box of width	1 Marks	Part-A
	10^{-10} meter. Its energy is 20 eV. The energy of the electron in its first exited		
	state is		
	Ans: 80 eV		
	Range: NA		
75	Ans: $E_3 = 2^2 E_1 = 4 \times 20 \text{ eV} = 80 \text{ eV}$	134 1	D
7B	An electron is confined in the ground state in a one-dimensional box of width 10^{-10} mater. Its energy is 20 eV. The energy of the electron in its second	1 Marks	Part-A
	10^{-10} meter. Its energy is 20 eV. The energy of the electron in its second exited state is		
	Ans: 180 eV		
	Range: NA Ans: $E_3 = 3^2 E_1 = 9 \times 20 \text{ e V} = 180 \text{ eV}$		
7C	An electron is confined in the ground state in a one-dimensional box of width	1 Marks	Part-A
	10^{-10} meter. Its energy is 30 eV. The energy of the electron in its first exited		
	state is		
	Ans: 120 eV		
	1 AMO. 120 C .		

	Range: NA		
9A	Ans: $E_3 = 2^2 E_1 = 4 \times 30 \text{ e V} = 120 \text{ eV}$ A particle of mass m , which moves freely inside an infinite potential	2 Marks	Part-B
	well of length a, has the following initial wave function at $t = 0$:		
	$\psi(x,0) = \frac{A}{\sqrt{a}}\sin\left(\frac{\pi x}{a}\right) + \sqrt{\frac{3}{5a}}\sin\left(\frac{3\pi x}{a}\right) + \frac{1}{\sqrt{5a}}\sin\left(\frac{5\pi x}{a}\right)$		
	In an experiment to measure the energy of the system, the value of the		
	energy comes out to be $E = \frac{h^2}{8ma^2}$. The corresponding probability		
	associated with the outcome of the measurement is : (Please provide exact value upto 2 decimal places)		
	Ans: 0.6 Range: NA		
	Range. 1471		
	$D_{0}^{(q)} = \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi x}{a}\right)$		
	They are witherward have (h) km) = & Pm - omm		
	: Y(x,0) = = = = = = = = = = = = = = = = = = =		
	$= A \beta(\alpha) + \sqrt{3} \beta_3(\alpha) + \sqrt{16} \beta(\alpha)$		
	Since $\psi(x_0)$ much be normalised $(\psi \psi)=1$ $\therefore \frac{A^2}{2} + \frac{3}{10} + \frac{1}{10} = 1 \implies A = \begin{cases} \frac{6}{5} \end{cases}$		
	$\psi(\mathbf{v},0) = \sqrt{\frac{3}{5}} \phi_1(\mathbf{x}) + \sqrt{\frac{3}{10}} \phi_3(\mathbf{x}) + \sqrt{\frac{1}{10}} \phi_5(\mathbf{x})$		
	:. For $\xi_1 \rightarrow P(\xi_1) = \langle \beta_1 \psi \rangle ^2 \Rightarrow_5$		
	$E_3 \rightarrow P(E_3) = \langle \beta_3 \psi \rangle ^2 = \frac{3}{10}$		
	$\xi_s \sim P(\xi_s) = \langle \phi_s \psi \rangle ^2 = 1/0$		
9B	A particle of mass m , which moves freely inside an infinite potential well of length a , has the following initial wave function at $t = 0$:	2 Marks	Part-B
	$\psi(x,0) = \frac{A}{\sqrt{a}} \sin\left(\frac{\pi x}{a}\right) + \sqrt{\frac{3}{5a}} \sin\left(\frac{3\pi x}{a}\right) + \frac{1}{\sqrt{5a}} \sin\left(\frac{5\pi x}{a}\right)$		
	In an experiment to measure the energy of the system, the value of the		
	energy comes out to be $E = \frac{9h^2}{8ma^2}$. The corresponding probability		
	associated with the outcome of the measurement is : (Please provide exact value upto 2 decimal places)		
	Ans: 0.3		
0.0	Range: NA	235	D. (P.
9C	A particle of mass m , which moves freely inside an infinite potential well of length a , has the following initial wave function at $t = 0$:	2 Marks	Part-B

		1	
	$\psi(x,0) = \frac{A}{\sqrt{a}} sin\left(\frac{\pi x}{a}\right) + \sqrt{\frac{3}{5a}} sin\left(\frac{3\pi x}{a}\right) + \frac{1}{\sqrt{5a}} sin\left(\frac{5\pi x}{a}\right)$ In an experiment to measure the energy of the system, the value of the energy comes out to be $E = \frac{25h^2}{8ma^2}$. The corresponding probability associated with the outcome of the measurement is: (Please provide exact value upto 2 decimal places)		
	Ans: 0.1		
10	Range: NA	4 1	.
10	The pair is not an orthonormal wavefunction:	1 mark	Part A
	(i). $\psi_1(x) = e^{-ax^2}$; (ii). $\psi_2(x) = xe^{-ax^2}$;		
	(iii). $\psi_3(x) = x^2 e^{-ax^2}$; (iv). $\psi_4(x) = x^3 e^{-ax^2}$		
	(\cdots) , $\varphi_3(\cdots)$		
	Choices: (a) (i),(ii)		
	(b) (i),(iii)		
	(c) (ii),(iii)		
	(d) (i),(iv)		
	(u) (1),(1v)		
	Ans: (b)		
	Range: NA		
	Ans: The integral of orthonormal functions is zero.		
	Check the pair for even function. The integral of the even function is non-		
	zero.		
	Or		
	You can calculate the overlapping integral of the pairs from $-\infty$ to ∞		
11	The values of A and B for the given wavefunctions are	2 marks	Part B
11	The values of A and B for the given wavefunctions are	2 marks	Tartb
	$\psi_1(x) = Ae^{-4x} \ \forall \ x > 0; \ \psi_2(x) = Be^{-4x^2}$		
	A		
	Ans : A=2.83; Range: 2.80 to 2.85		
	B=1.26; Range: 1.22 to 1.30		
	Ans:		
	$\psi_1(x) = Ae^{-4x} \ \forall \ x > 0;$ $\psi_1(x) = Be^{-4x^2};$		
	$\begin{bmatrix} \infty & -8x \end{bmatrix}^{\infty} \qquad \begin{bmatrix} \infty & \infty & 2 & 2x^2 & 2x^2 \end{bmatrix}$		
	$\int_{0}^{\infty} A^{2} e^{-8x} dx = 1 \Rightarrow A^{2} \frac{e^{-8x}}{-8} \Big _{0}^{\infty} = 1; \qquad \int_{0}^{\infty} B^{2} e^{-8x^{2}} dx = 1 \Rightarrow B^{2} \sqrt{\frac{\pi}{8}} = 1;$		
	$\begin{vmatrix} \mathbf{j} \\ 0 \end{vmatrix} = \begin{vmatrix} $		
	$A^2 = 8; \Rightarrow A = 2\sqrt{2} = 2.83$ $B^2 = \sqrt{\frac{8}{\pi}}; \Rightarrow B = 1.26$		
	$A = \delta; \Rightarrow A = 2\sqrt{2} = 2.83$ $B' = \sqrt{\frac{-}{\pi}}; \Rightarrow B = 1.20$		
	170		
		<u>l</u>	<u> </u>

12	Which of the following functions would make satisfactory	1 mark	Part A
	wavefunctions		
	(a). $\psi_1(x) = Ae^{a x }$; (b). $\psi_2(x) = Ae^{-ax^2}e^{-\frac{i}{\hbar}Et}$;		
	(c). $\psi_3(x) = \frac{A}{x-4} e^{-ax^2}$; (d). $\psi_4(x) = A e^{-ax} e^{-\frac{i}{\hbar}Et}$		
	(c). $\psi_3(x) - \frac{1}{x-4}e^{-x}$, (d). $\psi_4(x) - Ae^{-x}e^{-x}$		
	Ans: (b)		
	Range: NA		
	Sol:		
	(a). $\psi_1(x) = Ae^{a x }$; function diverges at $x = \pm \infty$		
	(b). $\psi_2(x) = Ae^{-ax^2}e^{\frac{i}{\hbar}Et}$; function is well behaved for all x		
	(c). $\psi_3(x) = \frac{A}{x-4} e^{-ax^2}$; function diverge at $x = 4$		
	(d). $\psi_4(x) = Ae^{-ax}e^{\frac{i}{\hbar}Et}$; function diverges at $x = -\infty$		
13	The wavefunction of a particle moving in the x-direction is	2 marks	Part B
	$\psi(x) = A x(7-x) \forall 0 < x < 7$		
	= 0; elsewhere		
	The value of Δx is		
	The value of Δx is		
	Ans: 1.32		
	Range: 1.25 to 1.40		
	Sol:		
	$\langle x \rangle = \int_{-\infty}^{\infty} x \psi ^2 dx = \int_{0}^{L} x \frac{30}{L^5} x^2 (L - x)^2 dx$		
	$= \frac{30}{L^5} \int_0^L (L^2 x^3 - 2Lx^4 + x^5) dx = 30L \left(\frac{1}{4} - \frac{2}{5} + \frac{1}{6} \right) = \frac{L}{2}$		
	$\langle x^2 \rangle = \int_{-\infty}^{\infty} x^2 \psi ^2 dx = \int_{0}^{L} x^2 \frac{30}{L^5} x^2 (L - x)^2 dx$		
	$= \frac{30}{L^5} \int_0^L (L^2 x^4 - 2Lx^5 + x^6) dx = 30L^2 \left(\frac{1}{5} - \frac{2}{6} + \frac{1}{7} \right) = \frac{2L^2}{7}$		
	Ans: $A = \sqrt{\frac{30}{L^5}}$; $\langle x \rangle = L/2$; $\langle x^2 \rangle = 2\frac{L^2}{7}$;		
	$\Delta x = \sqrt{\langle x \rangle^2 - \langle x^2 \rangle} = \sqrt{7} / 2 = 1.32$		
	An electron is free between 0 and 7 nm, defined through a given		
	wavefunction		
	$\psi(x) = A x(7-x) \forall 0 < x < 7$		
14	= 0; elsewhere		
	The average energy (<e>) is</e>	2 marks	Part B
	Ans: 7.8 meV		
	Range: 7.5 meV to 7.9 meV		
	Sol:		

$= \int_{-\infty}^{\infty} \psi^* \left(\frac{-\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} \right) dx = \frac{30}{L^5} \frac{-\hbar^2}{2m} \int_0^L x(L-x) \frac{\partial^2}{\partial x^2} (x(L-x)) dx$	
$= \frac{30 \hbar^2}{L^5 m} \int_0^L x(L - x) \mathrm{d}x = \frac{30 \hbar^2}{L^5 m} L^3 \left(\frac{1}{2} - \frac{1}{3} \right) = \frac{5 \hbar^2}{m L^2}$	
$\langle E \rangle = \int_{-\infty}^{+\infty} \psi^*(x) \left(-\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} \right) \psi(x) dx$	
$=\frac{30}{7^5}\left(-\frac{\hbar^2}{2m}\right)\int_0^7 x(7-x)\frac{\partial^2}{\partial x^2}x(7-x)dx$	
$= \frac{5 \hbar^2}{m 7^2} = \frac{5 \times \left(1.055 \times 10^{-24}\right)^2}{9.11 \times 10^{-31} \times 49 \times 10^{-18}} \frac{1 eV}{1.6 \times 10^{-19}} = 7.8 m \text{eV}$	