



VIT

Vellore Institute of Technology
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REG.NO.:

SLOT: F2+TF2

SCHOOL OF COMPUTER SCIENCE AND ENGINEERING CONTINUOUS ASSESSMENT TEST - I WINTER SEMESTER 2025-2026

Programme Name & Branch : B.Tech. (SCOPE)
Course Code and Course Name : BAPHY105- Engineering Physics
Faculty Name(s) : Anuj Ram Baitha, Samir Ranjan Meher, Rambabu Yalavarthi, Abhinav Anand, Laxmi Narayan Tripathi, Pankaj Sheoran, Kanhaiya Lal Pandey Sridhar S., Ankush 3683, 3685.
Class Number(s) : VL2025260503669, 3671, 3673, 3675, 3677, 3679, 3681, 3683, 3685.
Date of Examination : 01/02/2026
Exam Duration : 90 minutes **Maximum Marks: 50**

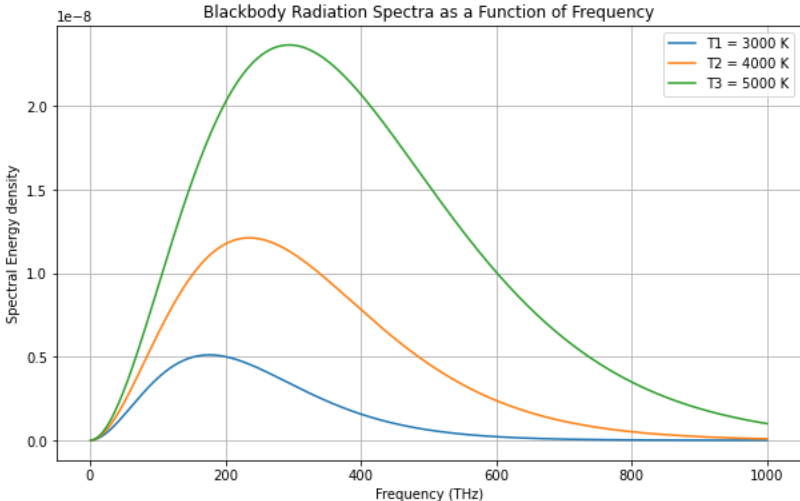
General instruction(s):

- Answer All Questions
- M - Max mark; CO – Course Outcome; BL – Blooms Taxonomy Level (1 – Remember, 2 – Understand, 3 – Apply, 4 – Analyse, 5 – Evaluate, 6 – Create)

Course Outcomes:

CO1: Identify limitations of classical physics through experimental observations.

CO2: Apply matrix algebra and Dirac notation for the understanding of quantum mechanical problems involving linear operators, eigenvalues, and eigenvector.

Q. No	Question	Module	Marks	CO	BL
1.	<p>Draw the blackbody spectra for an object kept at three different temperatures T_1, T_2, and T_3 ($T_3 > T_2 > T_1$). Discuss the Ultraviolet catastrophe with appropriate diagram and explain how Planck's hypothesis resolved it.</p> <p>blackbody spectra for three different temperatures T_1, T_2, and T_3 ($T_3 > T_2 > T_1$) as shown below- 2 Marks</p>  <p>Ultraviolet catastrophe with diagram as shown below- 3 Marks Classical Prediction (Rayleigh-Jeans Law): Classical physics used the Rayleigh-Jeans law to describe the energy emitted by a blackbody as a function of frequency.</p>	1	10	1	2



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According to the Rayleigh-Jeans law, the energy radiated increases proportionally to the square of the frequency

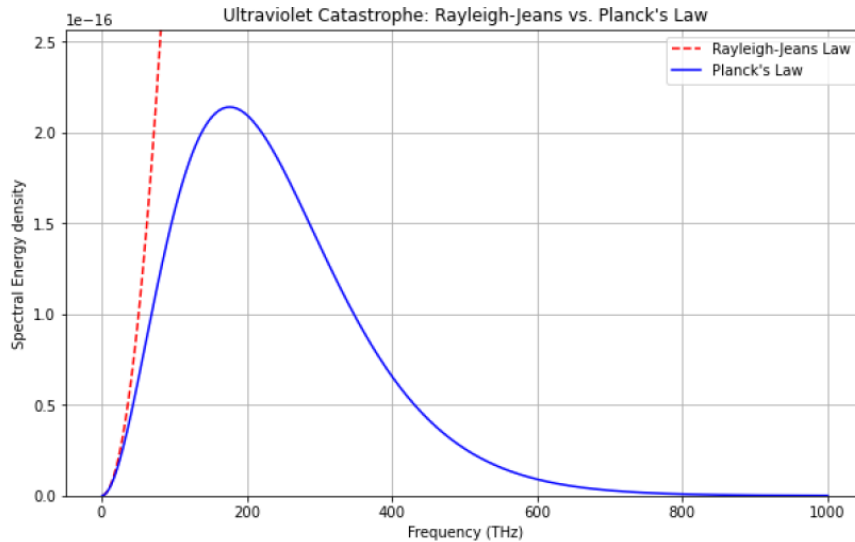
$$u(\nu) d\nu = \bar{\epsilon}G(\nu) d\nu = \frac{8\pi kT}{c^3} \nu^2 d\nu$$

This led to the prediction that, as frequency increases, the energy radiated by the blackbody would become infinitely large. This divergence at high frequencies (in the ultraviolet region) was known as the "ultraviolet catastrophe."

Experimental results:

Experiments showed that blackbody radiation peaks at a certain frequency and then decreases for higher frequencies.

This stark mismatch between theory and experiment highlighted a significant flaw in classical physics.



Explain how Planck's hypothesis resolved it- **5 Marks**

Planck's Quantum Theory:

Max Planck proposed a groundbreaking solution in 1900. He introduced the idea that energy is emitted or absorbed in discrete packets (quanta), where the energy of each packet is proportional to its frequency:

Using this quantization approach, Planck derived a new formula for blackbody radiation:

$$u(\nu) d\nu = \frac{8\pi h}{c^3} \frac{\nu^3 d\nu}{e^{h\nu/kT} - 1}$$

This law resolved the divergence at high frequencies and matched experimental data perfectly



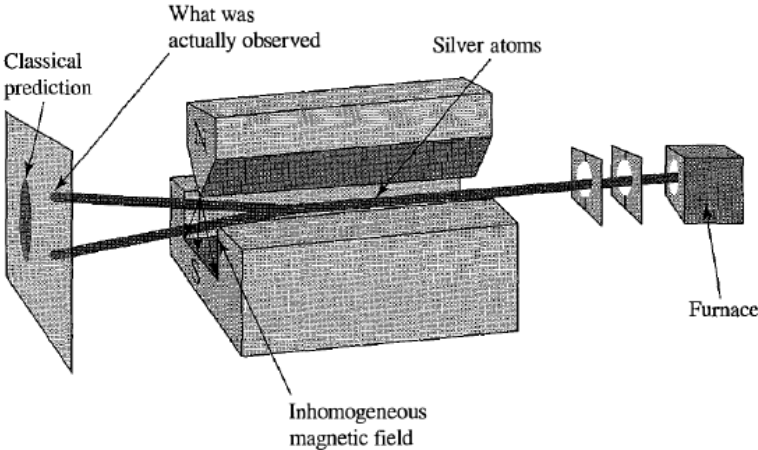
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<p>2.</p>	<p>What are matter waves? Describe an experiment that can demonstrate the concept of dual nature of matter, using appropriate diagrams. Matter waves brief: 3 marks Matter waves, or de Broglie waves, are a fundamental quantum mechanical concept proposing that all moving particles—electrons, protons, and even whole atoms—exhibit wave-like behavior. The wavelength of a particle is given by: $\lambda = h/p = h/mv$. Young’s double slit experiment demonstrating dual nature of matter when being observed and otherwise+ diagram: 7 marks Wave Nature (Interference): When electrons pass through two slits, they diffract and interfere with themselves, creating alternating bright (constructive) and dark (destructive) fringes on a detection screen. Particle Nature (Detection): Despite the wave-like propagation, the detector records individual, discrete, point-like arrivals (clicks or spots), indicating the entity arrived as a particle. Wave-Particle Duality: The experiment demonstrates that the entity behaves like a wave during propagation (interference) and a particle upon interaction with the screen</p>	<p>1</p>	<p>10</p>	<p>1</p>	<p>2</p>
<p>3.</p>	<p>a) Elucidate and analyse the experiment that led to the discovery of quantized electronic spins. Stern Gerlach Experiment: Explanation and diagrams: 5 marks This experiment was performed by Otto Stern and Walther Gerlach in 1922. <ul style="list-style-type: none"> • A beam of silver atoms is produced by heating silver in an oven. • These atoms come out through a small hole and form a narrow beam. • The beam passes through a region where there is a magnetic field that varies with position. • After that, the atoms hit a screen or detector.  </p>	<p>1</p>	<p>5</p>	<p>1</p>	<p>3</p>



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	<p>What do we expect classically? Classically, if the electron behaves like a tiny spinning charged object (like a rotating ball), it would have a magnetic moment. Because the atoms are randomly oriented, we would expect to see a continuous spread on the detector - atoms deflected in many directions depending on their magnetic moment. So we might expect a broad smear on the detector screen. What do we see in reality? Surprisingly, the beam does not spread out smoothly. Instead, the beam splits into exactly two spots - one slightly above and one slightly below the central line. This is something that classical physics cannot explain! This result suggests that the magnetic moment (and hence, the property called spin) of the electron can only take two possible values along the direction of the magnetic field - either “up” or “down”.</p>				
	<p>b) Determine the ratio of the corresponding wavelengths of a moving electron and a photon if both have same energy. Photon Wavelength (λ_p): Calculated as $\lambda_p = \frac{hc}{E}$. Electron Wavelength (λ_e): Calculated using the de Broglie formula $\lambda_e = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$ Ratio Formula: Dividing λ_p by λ_e yields $\frac{\lambda_p}{\lambda_e} = \frac{hc}{E} \div \frac{h}{\sqrt{2mE}} = c\sqrt{\frac{2m}{E}}$. (2+2+1 marks)</p>	1	5		
4.	<p>a) What conditions must a set of vectors satisfy to be called a <i>linear vector space</i>? Explain with suitable examples. Conditions governing Vector addition and Scalar Multiplication: 4 marks Example: 1 mark Vector addition satisfies the following rules: - Commutative: $\alpha\rangle + \beta\rangle = \beta\rangle + \alpha\rangle$ - Associative: $\alpha\rangle + (\beta\rangle + \gamma\rangle) = (\alpha\rangle + \beta\rangle) + \gamma\rangle$ - There exists a zero vector $0\rangle$ such that: $\alpha\rangle + 0\rangle = \alpha\rangle$ - Every vector has an additive inverse (or negative) such that: $\alpha\rangle + (- \alpha\rangle) = 0\rangle$ Scalar multiplication satisfies: - Distributivity over vector addition: $a(\alpha\rangle + \beta\rangle) = a \alpha\rangle + a \beta\rangle$ - Distributivity over scalar addition: $(a + b) \alpha\rangle = a \alpha\rangle + b \alpha\rangle$</p>	2	5	2	3



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	<p>- Associativity of scalar multiplication: $a(b \alpha \rangle) = (ab) \alpha \rangle$ - Multiplying by 1 and 0 gives: $1 \alpha \rangle = \alpha \rangle, 0 \alpha \rangle = 0 \rangle$ \mathbb{R}^n (Euclidean Space) can be used as an example.</p> <p>b) Consider the following two vectors:</p> $ \psi \rangle = \begin{pmatrix} 5i \\ 2 \\ -i \end{pmatrix}, \quad \phi \rangle = \begin{pmatrix} 3 \\ 8i \\ -9i \end{pmatrix}$ <p>Find $\psi \rangle^*$ and $\langle \psi$</p> <p>Solution (a) The expressions of $\psi \rangle^*$ and $\langle \psi$ are given by</p> $ \psi \rangle^* = \begin{pmatrix} -5i \\ 2 \\ i \end{pmatrix}, \quad \langle \psi = (-5i \ 2 \ i),$	2	5	
5.	<p>a) Given vectors $u \rangle = \begin{pmatrix} 1 \\ 2 \end{pmatrix} \in \mathbb{R}^2$ and $v \rangle = \begin{pmatrix} 3 \\ 4 \\ 5 \end{pmatrix} \in \mathbb{R}^3$, find the tensor product $u \otimes v$ and its dimension.</p> $ u \rangle \otimes v \rangle = \begin{pmatrix} 1 \cdot \begin{pmatrix} 3 \\ 4 \\ 5 \end{pmatrix} \\ 2 \cdot \begin{pmatrix} 3 \\ 4 \\ 5 \end{pmatrix} \end{pmatrix} = \begin{pmatrix} 1 \cdot 3 \\ 1 \cdot 4 \\ 1 \cdot 5 \\ 2 \cdot 3 \\ 2 \cdot 4 \\ 2 \cdot 5 \end{pmatrix} = \begin{pmatrix} 3 \\ 4 \\ 5 \\ 6 \\ 8 \\ 10 \end{pmatrix}$ <p>(3 marks)</p> <p>$\text{Dim}(\mathbb{R}^2 \otimes \mathbb{R}^3) = 2 \times 3 = 6$ (2 marks)</p>	2	4	2 3
	<p>b) Consider the states:</p> $ \psi \rangle = \frac{1}{\sqrt{5}} i \alpha \rangle + 2 \beta \rangle \quad \text{and} \quad \phi \rangle = \frac{1}{\sqrt{3}} \alpha \rangle + i \beta \rangle$ <p>where the two vectors, $\alpha \rangle$ and $\beta \rangle$ form a complete and orthonormal basis.</p> <p>(i) Check whether $\psi \rangle$ and $\phi \rangle$ are normalized function (ii) Calculate the inner product $\langle \psi \phi \rangle$</p>	2	6	



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	<p>(a) Check whether $\psi\rangle$ and $\phi\rangle$ are normalized</p> <p>1. For $\psi\rangle$:</p> $\langle\psi \psi\rangle = \frac{1}{5} [i^*i\langle\alpha \alpha\rangle + 2^*2\langle\beta \beta\rangle + (\text{cross terms})]$ <p>Cross terms vanish due to orthogonality.</p> $= \frac{1}{5}(1 + 4) = 1 \Rightarrow \boxed{ \psi\rangle \text{ is normalized}}$ <hr/> <p>2. For $\phi\rangle$:</p> $\langle\phi \phi\rangle = \frac{1}{3} [\langle\alpha \alpha\rangle + i^*i\langle\beta \beta\rangle + (\text{cross terms})] = \frac{1}{3}(1 + 1) = \frac{2}{3}$ <p style="text-align: center;">$\boxed{ \phi\rangle \text{ is not normalized}}$</p> <p style="text-align: right;">(3 marks)</p>				
	<p>(b) Calculate scalar product $\langle\psi \phi\rangle$</p> $\langle\psi \phi\rangle = \left(\frac{1}{\sqrt{5}}(i\langle\alpha + 2\langle\beta)\right) \left(\frac{1}{\sqrt{3}}(\alpha\rangle + i \beta\rangle)\right)$ <p>Multiply:</p> $= \frac{1}{\sqrt{15}} [i\langle\alpha \alpha\rangle + i^2 \cdot 2\langle\beta \beta\rangle + 0] = \frac{1}{\sqrt{15}} [i - 2]$ <p style="text-align: center;">$\boxed{\langle\psi \phi\rangle = \frac{i - 2}{\sqrt{15}}}$</p> <p style="text-align: right;">(2 marks)</p>				

