PRACTICE Quantum Detanglers

Division B

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(Answer Key at END)

Constants

Speed of Light	c	3e8 m/s
Mass of Electron	m_e	9.11e-31 kg
		0.511 MeV/c^2
Mass of Proton	m_n	1.673e-27 kg
		938.3 MeV/c^2
Mass of Neutron	m_n	1.675e-27 kg
		939.6 MeV/c^2
Electron charge	e	1.6e-19 C
Electron Volt	eV	1.6e-19 J
Planck's Constant	h	6.626e-34 J s
		4.135e-15 eV s
Reduced Planck's Constant	$\hbar$	1.054e-34 J s
		0.658e-15 eV s

Quantum Mechanics

Isaac is heating up a perfect black body. He discovers that the intensity of the emitted black-body radiation at lower frequencies is proportional to the temperature. He wants to use an equation to predict the intensity of his black-body radiation at all wavelengths based on temperature.

Which of the below equations does this? (Circle all that apply)

a) Rayleigh-Jeans Law
b) Wien's Displacement Law
c) Einstein-Planck Law
d) Bohr's Radiation Law
e) Stefan-Boltzmann Law

Isaac chooses the Rayleigh-Jeans Law to model his black-body data. He notices that the equation poorly models the intensity at high frequencies. What is the error between his experimental and theoretical data?

a) The experimental data is much higher than the theoretical model.
b) The experimental data is both higher and lower than the theoretical model.
c) The experimental data is much lower than the theoretical model.

What is the name of this historical physics problem between experiment and theory?

a) Infinite Intensity Problem
b) Light Conservation Postulate
c) Ultraviolet Catastrophe
d) Ehrenfest Problem

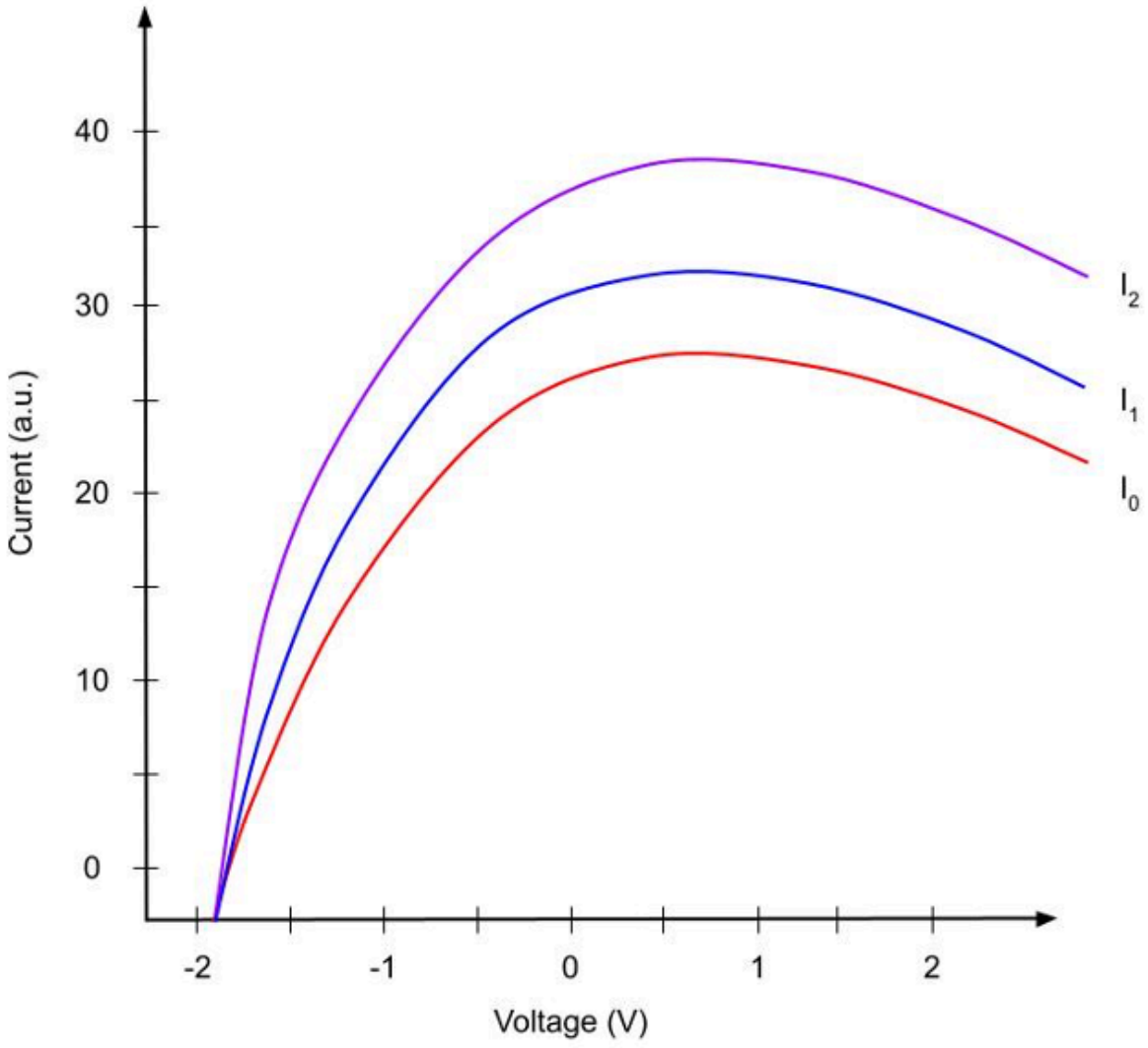
Who solved this problem?

a) Niels Bohr
b) Max Planck
c) Max Born
d) Albert Einstein

Isaac measures the intensity at a frequency of 10^{10} Hz. What is the difference in energy levels at this frequency?

a) 6.626E-24 J
b) 3.923 eV
c) 6.032E-20 J
d) 0.345 eV

Irene wanted to prove the photoelectric effect for herself. She decides to recreate the Lenard experiment. Shining a monochromatic light of wavelength 325nm on the cathode, she gets the following photoelectric current vs. voltage graph.



What is the stopping potential of this experimental setup?

a) 0.5V
b) -2V
c) 1.9V
d) 1V

List the light intensity of the three curves from greatest to least.

a) I_0, I_1, I_2
b) I_1, I_0, I_2
c) I_2, I_0, I_1
d) I_2, I_1, I_0

What is the work function of the unknown cathode metal?

a) 1.900 eV
b) 1.915 eV
c) 3.815 eV
d) 0.190 eV

Murray is replicating the Davisson-Germer experiment. He is looking for an electron beam source. What emission source was used in the original experiment?

a) Cold-field emission
b) Thermionic emission
c) Schottky emission

Once Murray has chosen the emission source, he selects two unknown monocrystalline metals as the target of the electron beam. Murray conducts the experiment such that the diffracted angle of the electron beam by the first metal is larger than the second, $\theta_1 > \theta_2$. What is the relationship between the spacing of the crystalline planes in the unknown metals, d_1 and d_2?

a) $d_1 > d_2$
b) $d_1 < d_2$
c) $d_1 = d_2$
d) The relationship cannot be determined from this information.

Which of the particles below in the Standard model has half integer spin (circle all that apply)?

a) Higgs-boson
b) Tau Neutrino
c) Gluon
d) Down Quark
e) Electron
a) Radius of the droplet

What ongoing physics experiment is based on the Michelson Interferometer?

a) CERN
b) ATLAS
c) JWST
d) LIGO

Jocelyn is observing a pion in a lab, which is a spin zero particle. Due to the unstable nature of pions, it soon decays into a muon and muon neutrino, which have half integer spins. Assuming that neither muon nor muon neutrino are initially observed, are they entangled?

a) Yes
b) No

Einstein's famous quote, *"spooky action at a distance"*, describes which quantum phenomena?

a) Quantum Tunneling
b) Quantum Entanglement
c) Quantum Nonlocality
d) Quantum Gravity

A violation of Bell's inequality necessarily means that the universe is non-local.

a) True
b) False

Does the super deterministic interpretation of Bell's Theorem violate Bell's inequality and how does it interpret causality?

a) Violates Bell's Inequality, Local Causality
b) Doesn't Violate Bell's Inequality, Local Causality
c) Violates Bell's Inequality, Non-Local Causality
d) Doesn't Violate Bell's Inequality, Non-Local Causality

Which of the following are critical assumptions made when deriving Bell's Inequality? (Circle all that apply)

a) Realism
b) Locality
c) Causality
d) Complementarianism

What is the largest number that can violate Bell's Inequality (Tsirelson's bound)?

a) 2
b) 4
c) 2
d) 4

Quantum Biology:

Explore the concept of magnetoreception in animals. How could the utilization of quantum properties contribute to their ability to sense Earth's magnetic field for navigation?

What is quantum coherence? Explain its role in photosynthesis in simple terms.

What is the lock and key model for enzyme-substrates?

What are key differences between MRI and NMR

1. What is a fundamental principle that quantum dots exploit for various applications?

a) Wave-particle duality
b) Chemical bonding
c) Electrostatic repulsion
d) Mechanical resonance

2. Which of the following biological processes is thought to be influenced by quantum effects in the context of magnetoreception?

a) Muscle contraction
b) Cellular respiration
c) Vision
d) Olfaction

Quantum Computing:

1) What is the fundamental unit of information in a quantum computer?
   a. Qubit
   b. Qubyte
   c. Quarkbit
   d. Quantum Byte
2) True or False: The Pauli-X gate is its own inverse.
   a. True
   b. False
3) Which quantum gate is commonly used for creating superposition states?
   a. Pauli-X Gate
   b. Hadamard Gate
   c. CNOT Gate
   d. Phase Gate
4) What is the primary application of the Deutsch-Jozsa Algorithm?
   a. Quantum Teleportation
   b. Solving systems of linear equations in constant time
   c. Identifying whether a function is constant or balanced
   d. Identifying the prime factors of large positive integers

5) Which of the following gates when applied twice brings the system back to its original state?

a. Hadamard Gate
b. Pauli-Z Gate
c. Pauli-Y Gate
d. Phase Gate

6) What is the role/function of a Bloch sphere?

a. Representing the geometry of a classical bit
b. Mapping classical bits to qubits
c. Demonstrating the effect of quantum gates in a circuit
d. Visualizes the possible states of a qubit

7) After applying the Pauli-Y gate to a qubit with state , what is the probability of measuring 1 in the resulting state?

a. 0
b. ¼
c. ½
d. ¾
e. 1

8) Which of the following is a quantum error correction code used to protect against single-qubit errors?

a. Bit Flip Code
b. Qubit Protection Protocol
c. Bit Error Correction Code
d. Qubit Correction Code

9) A qubit is in state $\alpha|0+\beta|1$. Given that $\alpha=(\sqrt{3})/8$, choose all possible values of β from the given options.

$(1-\sqrt{3})/8$
$(1+\sqrt{3})/8$
$-(\sqrt{5})/8$
$(\sqrt{5})/8$

10) What is the probability of measuring a 1 when a qubit is in the state $i/2|0>+(i\sqrt{3})/2|1>$?

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11) What is the probability of measuring a 1 when a qubit is in the state $i/2|0>+(i\sqrt{3})/2|1>$?

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ANSWER KEY

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Magnetoreception refers to the ability of certain animals to detect and navigate using Earth's magnetic field. Many animals use magnetoreception for orientation, navigation during migration, and finding their way back to specific locations

Quantum Coherence and Entanglement: Quantum coherence, the property of quantum systems to maintain phase relationships among their constituent particles, and entanglement, the phenomenon where particles become correlated in such a way that the state of one particle instantaneously influences the state of another, could play roles in enhancing the sensitivity and precision of magnetoreception mechanisms. These quantum phenomena may enable animals to process and amplify magnetic signals more effectively, allowing for more accurate navigation over long distances.

What is quantum coherence? Explain its role in photosynthesis in simple terms.
Quantum coherence is a property of quantum systems where particles, such as electrons or photons, exhibit wave-like behavior and maintain phase relationships with each other. In photosynthesis, quantum coherence plays a role in the efficient transfer of energy within light-harvesting complexes, such as chlorophyll molecules, in photosynthetic organisms like plants and algae.

What is the lock and key model for enzyme-substrates?

Specificity: Enzymes exhibit specificity for their substrates, meaning that they can recognize and bind only to certain molecules with complementary shapes and chemical properties.
Binding and Reaction: Once the substrate binds to the enzyme's active site, a chemical reaction occurs, resulting in the formation of a product. The active site provides an optimal environment for the reaction to take place, facilitating the conversion of the substrate into the product.

Induced Fit: In some cases, the enzyme-substrate interaction involves conformational changes in both the enzyme and the substrate, leading to a more precise fit between them.

What are key differences between MRI and NMR
MRI is primarily used in medical imaging to visualize anatomical structures and detect pathological conditions in the human body, such as tumors, injuries, and neurological disorders.
NMR is a broader scientific technique used in various fields, including chemistry, biochemistry, physics, and materials science, for studying the structure, dynamics, and interactions of molecules and materials.

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