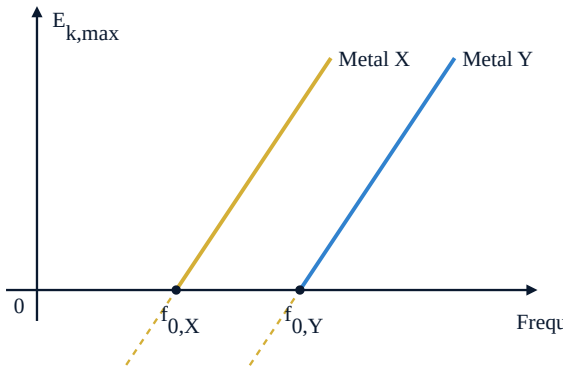
Topic: Quantum Physics

Instructions: Choose the best answer for each of the 30 questions. Topics cover the Photoelectric Effect, Photons, Work Function, Threshold Frequency, and De Broglie Wavelength. Assume standard physical constants: $h = 6.63 \times 10^{-34}\ \text{J s}$, $c = 3.00 \times 10^{8}\ \text{m s}^{-1}$, $e = 1.60 \times 10^{-19}\ \text{C}$, and $m_e = 9.11 \times 10^{-31}\ \text{kg}$.

1 The graph shows the maximum kinetic energy $E_{k,\text{max}}$ of emitted photoelectrons plotted against the frequency f of incident light for two different metals, X and Y. Which of the following statements correctly identifies the physical significance of the graph's features?



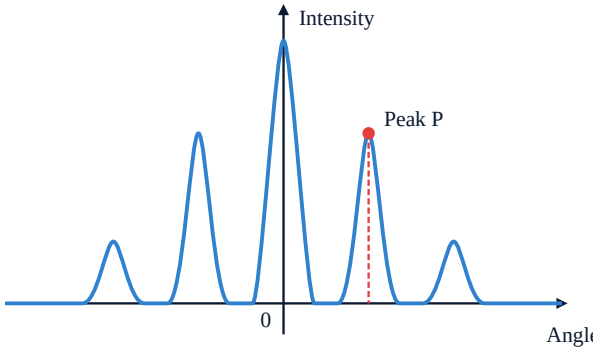
A. The gradient of both lines represents the work function, and Metal Y has a larger work function.

B. The gradient represents Planck's constant, and Metal Y has a larger work function than Metal X.

C. The x-intercept represents the work function, which is identical for both metals.

D. The y-intercept represents Planck's constant, which is a universal constant.

2 The graph shows the relative intensity (electron count rate) against the diffraction angle θ for electrons passing through a polycrystalline film. A central bright maximum is observed, surrounded by symmetric secondary rings. If the accelerating voltage of the electron gun is strictly increased, what physically happens to the position of the first-order peak (marked P)?



A. Peak P shifts to a larger angle θ.

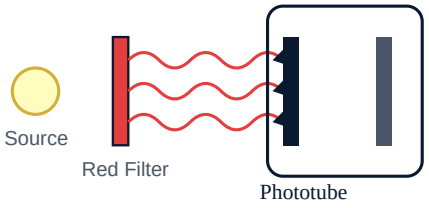
B. Peak P shifts to a smaller angle θ.

C. Peak P remains at the same angle, but its intensity increases.

D. Peak P vanishes completely due to destructive interference.

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3 The diagram depicts a simplified experimental arrangement where a phototube is irradiated with white light passing through a variable color filter. The ammeter measures the photocurrent. When a strict monochromatic red filter is used, the ammeter reads zero regardless of the light intensity. What is the fundamental physical reason for this observation?



A. The red filter completely absorbs all photons emitted by the source.

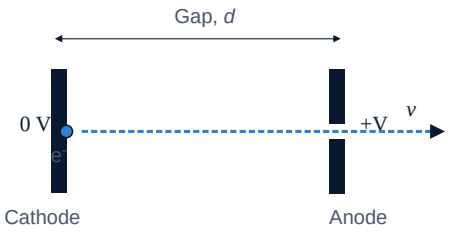
B. Red photons carry insufficient momentum to dislodge electrons.

C. The energy of a single red photon is less than the work function of the cathode.

D. The intensity of the red light is too low to produce a measurable current.

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4 An electron is released from rest at the negative plate (cathode) of an electron gun and accelerates across a vacuum gap towards an anode with a small central hole. The potential difference is V. Which expression physically dictates the final velocity v of the electron as it exits the anode hole, ignoring relativistic effects?



A. $v = \frac{eV}{m}$

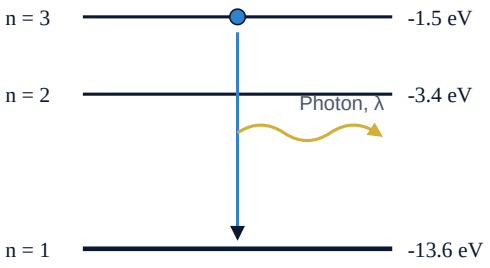
B. $v = \sqrt{\frac{2eV}{m}}$

C. $v = \frac{1}{2}mV^2$

D. $v = \sqrt{\frac{eV}{2m}}$

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5 The diagram shows the discrete atomic energy levels of a simple atom. An electron transitions from state $n = 3$ to $n = 1$, emitting a photon. Mathematically, what is the exact wavelength λ of this emitted photon? (Use $hc = 1240\ \text{eV nm}$).



A. $91\ \text{nm}$

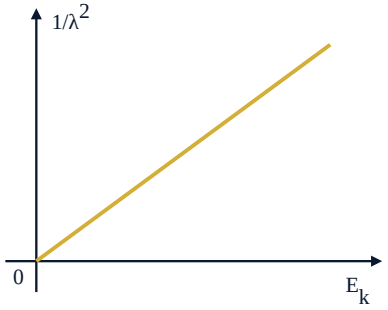
B. $102\ \text{nm}$

C. $122\ \text{nm}$

D. $656\ \text{nm}$

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6 A student plots a graph of $\frac{1}{\lambda^2}$ on the y-axis against the kinetic energy E_k on the x-axis for a non-relativistic moving electron, where λ is its De Broglie wavelength. What does the gradient of this strictly linear graph represent algebraically?



A. $\frac{2m}{h^2}$

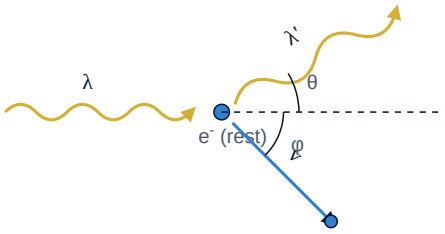
B. $\frac{h^2}{2m}$

C. $\sqrt{2mh}$

D. $\frac{1}{2mh}$

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7 The diagram shows a photon undergoing Compton scattering after a direct collision with a stationary free electron. According to the strictly defined physical principles of this interaction, which mathematical relationship correctly compares the incident wavelength λ and the scattered wavelength λ'?



A. $\lambda' < \lambda$ because the photon gains energy from the collision.

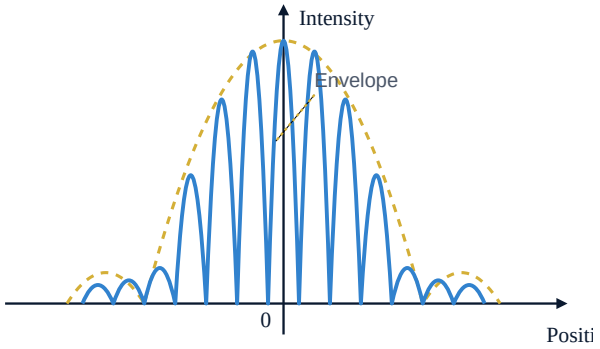
B. $\lambda' = \lambda$ because photon energy is rigorously conserved.

C. $\lambda' > \lambda$ because the photon transfers energy to the recoil electron.

D. The relationship strictly depends on the initial phase of the photon.

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8 The graph shows the relative intensity (electron count rate) against the position x on a screen for electrons passing through a double-slit arrangement. An interference pattern of fine fringes is observed. What does the macroscopic envelope of this interference pattern (indicated by the dashed gold line) represent physically?



A. The single-slit diffraction pattern of each individual slit.

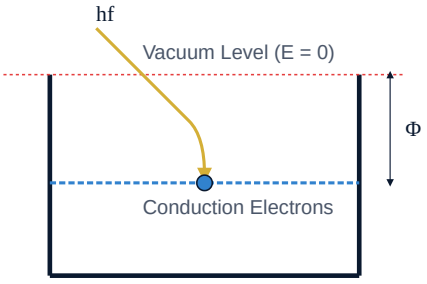
B. The distribution of kinetic energies of the incident electrons.

C. The purely particle-like ballistic trajectory of the electrons.

D. The continuous probability density of finding a single electron.

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9 The diagram represents the 'potential well' model of conduction electrons in a metal. An electron requires a minimum energy to escape the surface, denoted as the Work Function Φ. If a photon of energy $E = hf$ strikes the electron, what does the depth of the well strictly correspond to?



A. The maximum kinetic energy of the emitted photoelectron.

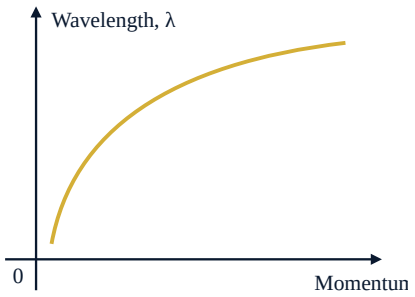
B. The energy gap between the highest occupied energy state and the vacuum level.

C. The total rest mass energy of the conduction electron.

D. The ionization energy of a single isolated metal atom.

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10 The graph below shows the strictly theoretical relationship between the De Broglie wavelength λ of a particle and its linear momentum p. Which fundamental equation is physically represented by the curve in this graph?



A. $\lambda = \frac{p}{h}$

B. $\lambda = hp$

C. $\lambda = \frac{h}{p}$

D. $\lambda = \sqrt{hp}$

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11 An electron and a proton are accelerated from rest through the identical potential difference V. What is the theoretical ratio of the De Broglie wavelength of the electron (λ_e) to that of the proton (λ_p)? (Let m_e and m_p represent their respective rest masses).

A. $\frac{\lambda_e}{\lambda_p} = 1$

B. $\frac{\lambda_e}{\lambda_p} = \frac{m_p}{m_e}$

C. $\frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}}$

D. $\frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_e}{m_p}}$

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12 A highly precise laser emits light of wavelength $633\ \text{nm}$ with a continuous power output of $5.0\ \text{mW}$. Calculate the exact number of photons emitted by the laser per second.

A. $1.6 \times 10^{15}\ \text{s}^{-1}$

B. $1.6 \times 10^{16}\ \text{s}^{-1}$

C. $3.1 \times 10^{15}\ \text{s}^{-1}$

D. $3.1 \times 10^{18}\ \text{s}^{-1}$

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13 Which of the following macroscopic objects exhibits a De Broglie wavelength that is physically most likely to be measurable using current scientific diffraction grating limits (e.g., interacting with atomic lattices $\sim 10^{-10}\ \mathrm{m}$)?

A. A $10\ \mathrm{g}$ bullet travelling at $300\ \mathrm{m\ s^{-1}}$.

B. A $1\ \mathrm{g}$ raindrop falling at terminal velocity.

C. A $10^{-15}\ \mathrm{kg}$ dust particle moving at $1\ \mathrm{mm\ s^{-1}}$.

D. None of the above. The wavelengths are orders of magnitude too small.

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14 In the context of the photoelectric effect, the existence of a 'Threshold Frequency' provides definitive proof of which fundamental quantum principle?

A. Light strictly propagates as a continuous transverse electromagnetic wave.

B. Electromagnetic energy is quantised into discrete, indivisible packets (photons).

C. Electrons exhibit wave-like diffraction properties.

D. The momentum of an electron is perfectly continuous.

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15 Monochromatic light of wavelength λ is incident on a metal with work function Φ. The stopping potential is measured as V_1. If light of wavelength $\frac{\lambda}{2}$ is then used on the same metal, the new stopping potential V_2 will rigorously adhere to which mathematical inequality?

A. $V_2 = 2V_1$

B. $V_2 < 2V_1$

C. $V_2 > 2V_1$

D. $V_2 = \frac{1}{2}V_1$

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16 Two distinct monochromatic light beams, A and B, illuminate a metal surface. Beam A contains N photons per second, each with energy 3Φ (where Φ is the work function). Beam B contains $3N$ photons per second, each with energy 0.5Φ. Compare the rates of photoelectron emission.

A. Beam B emits three times as many electrons per second as Beam A.

B. Beam A emits electrons; Beam B emits absolutely none.

C. Both beams emit the exact same number of electrons per second.

D. Beam B emits electrons with higher maximum kinetic energy.

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17 A metallic surface has a threshold wavelength of $550\ \text{nm}$. It is illuminated by ultraviolet light of wavelength $220\ \text{nm}$. Calculate the required stopping potential V_s to halt the fastest photoelectrons.

A. $2.26\ \text{V}$

B. $3.39\ \text{V}$

C. $5.65\ \text{V}$

D. $7.91\ \text{V}$

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18 (BPhO Extension) According to special relativity and quantum mechanics, a photon possesses zero rest mass. However, it exerts a gravitational pull and carries momentum. What is the theoretical 'equivalent mass' m of a single photon of frequency f?

A. $m = \frac{hf}{c}$

B. $m = \frac{hf}{c^2}$

C. $m = \frac{hc}{f}$

D. $m = 0$ exclusively under all mathematical frameworks.

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19 The wave theory of light utterly fails to explain the photoelectric effect because classically, a low-intensity, low-frequency wave should eventually eject an electron if given enough time to 'build up' energy. Experimentally, emission is virtually instantaneous ($< 10^{-9}$ s). This instantaneous nature supports what property of photons?

A. They travel slightly faster than the classical speed of light c in a vacuum.

B. They possess localized energy that transfers entirely in a 1-to-1 particle collision.

C. They undergo constructive interference at the metal surface.

D. They possess a negative electrostatic charge.

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20 (BPhO Extension) An electron is perfectly trapped within a one-dimensional, infinitely deep quantum well of width L. By equating the width L to the conditions for a standing De Broglie wave (where nodes must strictly exist at the boundaries), what is the correct expression for the allowed kinetic energies E_n of the electron?

A. $E_n = \frac{nh^2}{8mL^2}$

B. $E_n = \frac{n^2h^2}{8mL^2}$

C. $E_n = \frac{n^2h}{4mL}$

D. $E_n = \frac{h^2}{2mL^2n}$

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21 In the Compton effect, an X-ray photon collides with an electron. The scattered photon has a longer wavelength than the incident photon. What fundamental conservation laws strictly dictate the derivation of the Compton shift formula?

A. Conservation of Rest Mass and Conservation of Charge.

B. Conservation of Relativistic Energy and Conservation of Vector Momentum.

C. Conservation of Angular Momentum exclusively.

D. Conservation of Wave Frequency and Conservation of Amplitude.

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22 An X-ray tube operates at an accelerating potential of $50.0\ \text{kV}$. What is the absolute minimum wavelength (λ_{min}) of the continuous X-ray bremsstrahlung spectrum produced? (Use $hc = 1.24 \times 10^{-6}\ \text{eV m}$).

A. $2.48 \times 10^{-11}\ \text{m}$

B. $2.48 \times 10^{-10}\ \text{m}$

C. $1.24 \times 10^{-11}\ \text{m}$

D. $6.20 \times 10^{-12}\ \text{m}$

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23 (BPhO Extension) A perfectly absorbing black surface of area A is illuminated normally by a laser beam of intensity I (power per unit area). Using the momentum of photons, what is the exact expression for the radiation pressure P exerted strictly on the surface?

A. $P = I \cdot c$

B. $P = \frac{I}{c}$

C. $P = \frac{2I}{c}$

D. $P = \frac{I}{c^2}$

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24 Heisenberg's Uncertainty Principle states $\Delta x \Delta p \geq \frac{h}{4\pi}$. If the uncertainty in an electron's position Δx is strictly reduced to the dimension of an atomic nucleus ($\sim 10^{-15}\ \text{m}$), what is the direct consequence for its De Broglie wavelength λ?

A. The wavelength becomes completely fixed and exact.

B. The wavelength must increase proportionally to match the nucleus size.

C. The uncertainty in the wavelength becomes extreme, rendering the concept of a single defined λ physically meaningless.

D. The wavelength collapses to exactly zero.

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25 If the linear momentum of a free particle is mathematically increased by 10%, what is the resulting percentage change in its theoretical De Broglie wavelength?

A. An increase of 10%.

B. A decrease of 10%.

C. A decrease of approximately 9.1%.

D. An increase of 100%.

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26 (BPhO Extension) A perfectly reflecting ultra-lightweight mirror of mass $m = 1.0\ \text{mg}$ is theoretically kept hovering in mid-air (against gravity $g = 9.81\ \text{m s}^{-2}$) exclusively by a laser beam directed vertically upwards. Calculate the immense continuous laser power P required.

A. $1.5\ \text{kW}$

B. $1.5\ \text{MW}$

C. $3.0\ \text{MW}$

D. $2.9 \times 10^{9}\ \text{W}$

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27 A metal surface is illuminated first by light of wavelength $400\ \text{nm}$, resulting in a stopping potential of $1.20\ \text{V}$. It is then illuminated by light of wavelength $300\ \text{nm}$, resulting in a stopping potential of $2.23\ \text{V}$. Using exclusively these two experimental values, what is the calculated value of Planck's constant h? (Assume $e = 1.60 \times 10^{-19}\ \text{C}$, $c = 3.0 \times 10^{8}\ \text{m s}^{-1}$).

A. $6.59 \times 10^{-34}\ \text{J s}$

B. $6.63 \times 10^{-34}\ \text{J s}$

C. $6.67 \times 10^{-34}\ \text{J s}$

D. $6.75 \times 10^{-34}\ \text{J s}$

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28 In an electron diffraction tube experiment, a thin graphite film is used to diffract a beam of electrons. The accelerating voltage is V. If the voltage is quadrupled to $4V$, by what factor does the De Broglie wavelength of the electrons change (ignoring relativistic effects)?

A. It increases by a factor of 2.

B. It decreases by a factor of 2.

C. It decreases by a factor of 4.

D. It remains unchanged because wavelength depends on mass, not voltage.

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29 Which of the following physical phenomena provides the most definitive evidence for the wave nature of matter?

A. The photoelectric effect.

B. Compton scattering of X-rays.

C. Electron diffraction through crystalline structures.

D. The continuous spectrum of black-body radiation.

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30 A photon of frequency f has exactly the same momentum as a free electron of mass m_e. What is the exact kinetic energy of the electron, expressed in terms of h, f, c, and m_e?

A. $\frac{h^2 f^2}{2m_e c^2}$

B. hf

C. $\frac{hf}{2m_e c}$

D. $m_e c^2 + hf$

Answer Key

Q1: **B**	Q2: **B**	Q3: **C**	Q4: **B**	Q5: **B**
Q6: **A**	Q7: **C**	Q8: **A**	Q9: **B**	Q10: **C**
Q11: **C**	Q12: **B**	Q13: **D**	Q14: **B**	Q15: **C**
Q16: **B**	Q17: **B**	Q18: **B**	Q19: **B**	Q20: **B**
Q21: **B**	Q22: **A**	Q23: **B**	Q24: **C**	Q25: **C**
Q26: **B**	Q27: **A**	Q28: **B**	Q29: **C**	Q30: **A**