Global Quantum Mechanics Science Challenge 2026

Qualification Round Submission

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Problem A: Electromagnetic Spectrum Regions

Step 1: What the image shows

The diagram runs left to right with wavelength decreasing from ~100m (building size) down to ~0.0001nm (atom size). The scale markers visible are: 100m → 1m → 1cm → 0.01cm → 1000nm → 10nm → 0.01nm → 0.0001nm. The visible spectrum sits roughly in the middle, anchored around 1000nm–400nm. The labels (a) through (e) are placed outside the visible band.

Step 2: Direction of energy

Since wavelength decreases left to right, and $E = hc/\lambda$, energy increases left to right. The labels run (a) → (b) → (c) → (d) → (e), which the problem confirms is in order of increasing energy.

Step 3: Matching labels to regions using wavelength ranges and reference objects

From the image:

- **(a)** sits in the far left, spanning roughly 100m down to ~1cm. Reference objects shown: AM tower, FM, TV, Radar. This is clearly **Radio waves**.
- **(b)** sits between ~0.01cm and ~1000nm, just before the visible spectrum. Reference object: TV Remote. TV remotes use infrared. Wavelength range ~1mm to ~700nm. This is **Infrared**.
- **(c)** sits immediately adjacent to the visible spectrum on the short-wavelength side, around 10nm–400nm. The reference object shown is the Sun. The Sun is a strong UV emitter. This is **Ultraviolet**.
- **(d)** spans roughly 10nm down to ~0.01nm. Reference object: X-ray machine. This is **X-rays**.
- **(e)** sits at the far right, below ~0.0001nm. Reference object: Radioactive elements / nuclear symbol. This is **Gamma rays**.

Step 4: Verify against standard spectrum order (increasing energy)

Radio → Microwave → Infrared → Visible → Ultraviolet → X-ray → Gamma ray ✓

Note: Microwave isn't one of the five named regions in the problem. The five given are radio, infrared, ultraviolet, X-ray, and gamma ray. The diagram skips a distinct microwave band or folds it into radio/infrared, which is consistent with how (a) spans a wide range.

Self-check: The problem states the five regions to identify are infrared, gamma rays, radio waves, ultraviolet, and X-rays. All five are accounted for.

Label	Region
(a)	Radio waves
(b)	Infrared
(c)	Ultraviolet
(d)	X-rays
(e)	Gamma rays

Problem B: Photon Energy of Red and Green Light

Given

Wavelength of red light: $\lambda_{red} = 650$ nm $= 650 \times 10^{-9}$ m

Wavelength of green light: $\lambda_{green} = 532$ nm $= 532 \times 10^{-9}$ m

Planck's constant: $h = 6.626 \times 10^{-34}$ J·s

Speed of light: $c = 3.00 \times 10^{8}$ m/s

Conversion factor: 1 eV $= 1.602 \times 10^{-19}$ J

Formula

$E = hc/\lambda$

Calculation

Red photon ($\lambda = 650 \times 10^{-9}$ m):

$E_{red} = (6.626 \times 10^{-34} \times 3.00 \times 10^{8}) / (650 \times 10^{-9})$

⇨ $E_{red} = 1.988 \times 10^{-25} / 6.50 \times 10^{-7}$
⇨ $E_{red} = 3.058 \times 10^{-19}$ J
⇨ $E_{red} = 3.058 \times 10^{-19} / 1.602 \times 10^{-19}$
⇨ $E_{red} = 1.91$ eV

Green photon ($\lambda = 532 \times 10^{-9}$ m):

$E_{green} = (6.626 \times 10^{-34} \times 3.00 \times 10^{8}) / (532 \times 10^{-9})$

⇨ $E_{green} = 1.988 \times 10^{-25} / 5.32 \times 10^{-7}$
⇨ $E_{green} = 3.736 \times 10^{-19}$ J
⇨ $E_{green} = 3.736 \times 10^{-19} / 1.602 \times 10^{-19}$
⇨ $E_{green} = 2.33$ eV

Verification: Since $\lambda_{green} < \lambda_{red}$ and $E = hc/\lambda$, a shorter wavelength gives higher energy. So $E_{green} > E_{red}$, which matches the results.

Final Answer

Red photon energy = 1.91 eV

Green photon energy = 2.33 eV

Problem C: Photoelectric Effect

(a)

Given

Work function: $\varphi = 2.3$ eV $h = 6.626 \times 10^{-34}$ J·s 1 eV $= 1.602 \times 10^{-19}$ J

Formula

$f0 = \varphi / h$

Calculation

Convert work function to Joules:

$\varphi = 2.3 \times 1.602 \times 10^{-19}$

⇨ $\varphi = 3.685 \times 10^{-19}$ J

Substitute into threshold frequency equation:

$f0 = 3.685 \times 10^{-19} / 6.626 \times 10^{-34}$

⇨ $f0 = 5.56 \times 10^{14}$ Hz

Final Answer

Minimum frequency $= 5.56 \times 10^{14}$ Hz

(b)

Given

Wavelength: $\lambda = 2500$ Å $= 2500 \times 10^{-10}$ m $= 2.50 \times 10^{-7}$ m

Work function: $\varphi = 2.3$ eV $h = 6.626 \times 10^{-34}$ J·s $c = 3.00 \times 10^{8}$ m/s 1 eV $= 1.602 \times 10^{-19}$ J

Formula

$E = hc/\lambda$ $KEmax = E - \varphi$

Calculation

Calculate photon energy:

$E = (6.626 \times 10^{-34} \times 3.00 \times 10^{8}) / (2.50 \times 10^{-7})$

⇨ $E = 1.988 \times 10^{-25} / 2.50 \times 10^{-7}$
⇨ $E = 7.950 \times 10^{-19}$ J

Convert photon energy to eV:

$E = 7.950 \times 10^{-19} / 1.602 \times 10^{-19}$

⇨ $E = 4.96$ eV

Verification: Photon energy (4.96 eV) > work function (2.3 eV), so electrons are emitted.

Apply Einstein's photoelectric equation:

$KEmax = 4.96 - 2.3$

⇨ $KEmax = 2.66$ eV

Convert to Joules:

$KEmax = 2.66 \times 1.602 \times 10^{-19}$

⇨ $KEmax = 4.26 \times 10^{-19}$ J

Final Answer

Maximum kinetic energy = 2.66 eV = 4.26×10^{-19} J

Problem D: Heisenberg Uncertainty Principle

(a)

Given

Speed of photoelectron: $v = 5 \times 10^5$ m/s

Mass of electron: $m = 9.109 \times 10^{-31}$ kg $h = 6.626 \times 10^{-34}$ J·s

Assumption: The problem asks to "estimate" the uncertainty in position. To get the minimum possible uncertainty, we take the equality and assume the uncertainty in momentum equals the full momentum of the particle, i.e., $\Delta p = mv$. This is standard practice for estimation problems in quantum mechanics competitions.

Formula

$\Delta x \Delta p \geq h/(4\pi)$

⇨ $\Delta x \geq h/(4\pi \times \Delta p)$

With $\Delta p = mv$:

$\Delta x = h/(4\pi \times mv)$

Calculation

Calculate momentum: $p = mv = 9.109 \times 10^{-31} \times 5 \times 10^5$

⇨ $p = 4.555 \times 10^{-25}$ kg·m/s

Calculate minimum position uncertainty:

$\Delta x = 6.626 \times 10^{-34} / (4\pi \times 4.555 \times 10^{-25})$

⇨ $\Delta x = 6.626 \times 10^{-34} / (4 \times 3.1416 \times 4.555 \times 10^{-25})$
⇨ $\Delta x = 6.626 \times 10^{-34} / 5.724 \times 10^{-24}$
⇨ $\Delta x = 1.158 \times 10^{-10}$ m
⇨ $\Delta x \approx 1.16 \times 10^{-10}$ m

Dimensional check: J·s / (kg·m/s) = kg·m^2·s^-1 / (kg·m·s^-1) = m. Units are consistent.

Final Answer

Minimum uncertainty in position of the photoelectron = 1.16×10^{-10} m

This is on the order of an atomic radius, which is physically significant and confirms that quantum uncertainty matters at this scale.

(b)

Given

Mass of person: m = 75 kg Speed: v = 3 m/s h = 6.626×10^{-34} J·s

Assumption: Same as part (a). We set $\Delta p = mv$ to estimate the minimum position uncertainty.

Formula

$\Delta x = h/(4\pi \times mv)$

Calculation

Calculate momentum:

$p = mv = 75 \times 3$

⇨ $p = 225$ kg·m/s

Calculate minimum position uncertainty:

$\Delta x = 6.626 \times 10^{-34} / (4\pi \times 225)$

⇨ $\Delta x = 6.626 \times 10^{-34} / (4 \times 3.1416 \times 225)$
⇨ $\Delta x = 6.626 \times 10^{-34} / 2827.4$
⇨ $\Delta x = 2.343 \times 10^{-37}$ m
⇨ $\Delta x \approx 2.34 \times 10^{-37}$ m

Dimensional check: J·s / (kg·m/s) = m. Units are consistent.

Final Answer

Minimum uncertainty in position of the person = 2.34×10^{-37} m

This is about 10^{27} times smaller than a proton, making it completely negligible and undetectable in everyday life.

Self-check

Δx (electron) = 1.16×10^{-10} m

Δx (person) = 2.34×10^{-37} m

The electron's position uncertainty is about 10^{27} times larger than the person's, which is exactly what the problem statement anticipates when it says uncertainties are significant in the quantum world but negligible in the macroscopic world. Both results are physically reasonable.

Problem E: Quantum Computing Applications

Two fields where quantum computers are expected to be especially useful are drug discovery and cryptography.

In drug discovery, simulating how molecules interact at the quantum level is computationally expensive for classical computers. Even a relatively small molecule like caffeine involves enough interacting electrons that an exact classical simulation becomes intractable. Quantum computers can model these interactions directly using superposition and entanglement, which could help researchers predict how drug candidates bind to proteins and speed up the development of new medicines significantly.

In cryptography, many current encryption systems rely on the difficulty of factoring very large numbers, a task that takes classical computers an impractically long time. Quantum computers running Shor's algorithm can factor large numbers exponentially faster. This has pushed governments and research institutions to work on post-quantum cryptography standards, since a sufficiently powerful quantum computer would break widely used protocols like RSA.

As for why laptops still outperform quantum computers for everyday tasks, the short answer is that quantum computers are not general-purpose machines. Current quantum processors require temperatures close to absolute zero to keep qubits stable, need heavy shielding from environmental noise, and suffer from high error rates because qubits are extremely fragile. A single stray vibration or electromagnetic fluctuation can cause decoherence, which destroys the quantum state mid-calculation. Error correction is possible but requires large numbers of physical qubits just to represent a single reliable logical qubit, and today's machines simply do not have enough of them.

Beyond the hardware problems, tasks like loading a webpage or editing a document involve sequential logic, file management, and constant input-output operations. These tasks do not have the kind of mathematical structure that quantum algorithms are designed to exploit. Quantum speedups only appear for specific problem types, mainly those involving large-scale search, simulation, or number theory. A classical laptop handles streaming video, multitasking, and everyday software with low latency and no exotic infrastructure, which a quantum computer cannot come close to matching today.

Quantum computing is a real and active research area, but current devices are best thought of as specialized tools for specific hard problems, not replacements for conventional computers.