

Quantum Quandary

2025 Washington Science Olympiad State Test

Names: _____

School: _____

Team Number: _____

Score: _____

Rank: _____

Page	1	2	3	4	5	6	7	8	9	10	total
Score											
Max	20	10	20	10	18	15	13	16	16	12	150

This is a long and challenging test. We recommend that you start by reading all the questions and select those on which you can best succeed. If and when you complete those questions, move on to others that are more challenging to you.

- Exam is 50 minutes long
- You can take the exam apart. Just make sure to staple the exam together in order at the end
- We will grant partial credit in many of the questions based demonstrating that you have basic comprehension of the specific topics. Show your work or the grader(s) will not have any chance to assess your level of knowledge.
- If you need clarification on any question, and the supervisor decides that all students should hear the clarification you are seeking, they will announce the question and clarification to the entire group.

Basic concepts and history of Quantum Physics

1. Consider a double slit experiment with a point source of electrons or photons a.

[2pts] What is the name of the man who first performed this experiment?

- a. Lester Germer
- b. Thomas Young
- c. Clinton Davisson
- d. George Thomson

b. [8pts] Draw an experimental set-up

c. [2pts] What do the results of this experiment demonstrate?

- a. That an electron beam is not coherent
- b. That electrons act like waves
- c. That electrons can pass through the barrier at spots between the slits
- d. That electrons show aspects of particle and wave behaviors

d. [4pts] Describe how the results of experiment change if sensing is provided for photon/electron detection at a slit.

2. [4pts] What must be true about two operators, if it is possible to know both observables at the same time?

3. [2pts] What aspect of Quantum Mechanics did the Einstein-Podolsky-Rosen Paradox question?

a. Entanglement

b. Interference

c. Decoherence

d. Superposition

4. [3pts] What is the minimum positional uncertainty for a 730 nm photon that has a momentum uncertainty of 0.3%?

5. [2pts] What transformation does the parity operator correspond to?

a. Translation

b. Rotation

c. Reflection

d. Dilation

6. [3pts] Consider the following superposition

$$\theta = \frac{1}{\sqrt{5}}f(x) + \frac{\sqrt{3}}{7}g(x)$$

What factor N must you multiply θ by to normalize it?

Atomic and Particle Physics

7. Answer the following questions about the photoelectric effect.

a. [2pts] The photoelectric effect shows light acting like a...

a. Particle

b. Wave

b. [2pts] What differentiates the photovoltaic effect from the photoelectric effect?

a. The photovoltaic effect results in electrons freed from the surface of an illuminated plate.

b. The photovoltaic effect results in the potential energy between the surfaces of the illuminated plate

c. The photoelectric effect can only be generated in semiconductor materials with a bandgap between .8 and 1.9V

d. None of the other answers

8. [10 pts] Name the 5 Bosons that have been observed experimentally.

1.

2.

3.

4.

5.

9. [6 pts] Draw the Feynman diagram of an electron positron annihilation process.

10. A non-relativistic electron of mass m is confined in vacuum between two metal plates separated by a distance L .

a. [4pts] Draw how the electron wave would look like between the plates at its minimum possible kinetic energy?

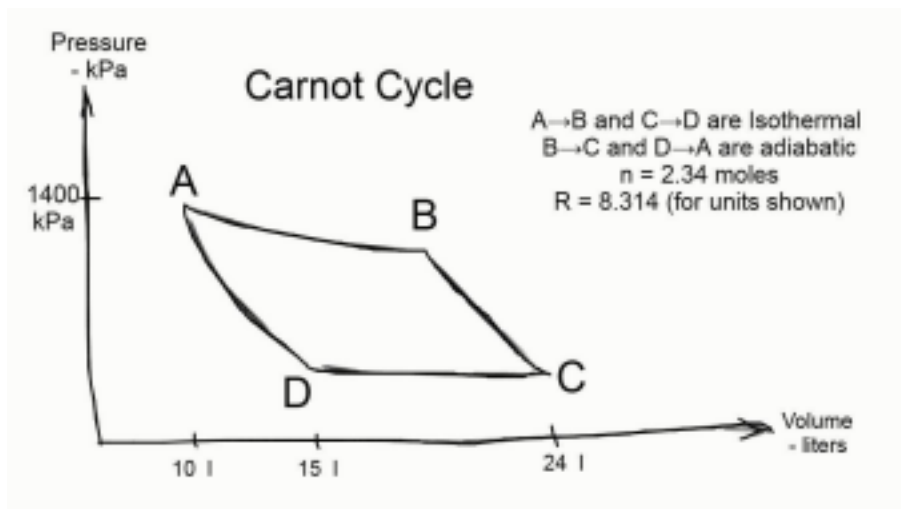
b. [3pts] What is the average momentum of the electron?

c. [3 pts] What is the formula for the energy of the electron in the n th mode?

Statistical Physics

11. [2 pt] The First Law of Thermodynamics describes the conservation of Energy. Write an equation that defines the Total Energy (E_{total}) of a system.
12. [4 pt] The Second Law of Thermodynamics describes the irreversibility of natural processes. The equation $\delta Q = T dS$ is a statement of the 2nd Law for complete systems. If δQ is heat transfer and T is absolute temperature, what does dS symbolize and what limit does the 2nd Law define for dS ?
13. [4 pts] The third Law of Thermodynamics describes absolute limits for systems in which all kinetic and potential energy has been removed from the system. This Law is captured in the equation $S = k_B \ln \Omega$. It defines the limit at absolute zero temperature or Ground state. The term S is consistent with the 2nd Law definition above, k_B is the Boltzmann constant. What does Ω symbolize? What is S at 0K?
14. [2pts] Which material has the largest specific heat capacity?
- | | |
|----------|-------------|
| a. Brass | b. Gold |
| c. Iron | d. Aluminum |
15. [2pts] How many vibrational degrees of freedom does a CH_4 molecule have?
- | | |
|-------|-------|
| a. 8 | b. 9 |
| c. 10 | d. 11 |
16. [2 pts] For a spontaneous process in an isolated system, what is the change in entropy?
- | | | |
|-------------------|-------------------|-------------------|
| a. $\Delta S < 0$ | b. $\Delta S = 0$ | c. $\Delta S > 0$ |
|-------------------|-------------------|-------------------|
17. [2pts] A reversible process can occur in a closed system?
- | | |
|---------|----------|
| a. True | b. False |
|---------|----------|

18. These questions all relate to a Carnot cycle engine that follows the following cycle path. The working fluid is a monatomic ideal gas. ($PV=nRT$ is valid.) Restrict answers to 3 significant figures.



- a. [3 pts] What is the Temperature at point B (T_B)?
- b. [3 pts] What is the Pressure at point D (P_D)?
- c. [3 pts] What is the Temperature at point C (T_C)?
- d. [3 pts] What is the Pressure at point C (P_C)?
- e. [3 pts] What is the Volume at Point B (V_B)?

Solid-State Material Science

19. [2pts] What is the bandgap energy of a good conductor? _____
20. [2pts] What is the bandgap energy of a good insulator? _____
21. [2pts] What would be a typical bandgap energy of Single Crystalline Silicon?
- a. 0.8 eV
 - b. 1.1 eV
 - c. 1.4 eV
 - d. 1.7 eV
22. [3pts] The ratio of electrons in the conductance band to valence band of a semiconductor is 5.27×10^{-36} at 300K. Predict the band gap energy.
23. [2pts] If a new superconductor was discovered that functioned at a temperature of 100K, what type would it be classified as?
- a. Type I
 - b. Type II
24. [2pts] If there are magnetic fields going through a material, what happens to that magnetic field when the material transitions into a superconductor?
- a. The magnetic field is expelled from material
 - b. The magnetic field is strengthened
 - c. The magnetic field is weakened
 - d. Nothing happens to the magnetic field

25. [2pts] For a two-level system with two electrons that are in the excited singlet-state, The net spin of all the electrons in the system is... _____

26. [2pts] For a two-level system with two electrons that are in the excited triplet-state, The net spin of all the electrons in the system is... _____

27. [2pts] The Pauli exclusion principle necessitates that a filled orbital will have a net 0 spin with a maximum of how many of electrons _____

28. [2pts] Nickel is a metal which is attracted by....

a. None of the magnetic poles of magnet

b. Both magnetic poles of magnet

c. North pole of magnet

d. South pole of magnet

29. [4pts] An electron has a magnetic dipole due to its spin. What is spin?

30. [4pts] Why does the carbon-13 isotope respond to an external magnetic field while the carbon-12 isotope does not.

Quantum Information Processing

31. The math governing Quantum Information Processing is different from Binary logic.

a. [4pts] In creating a programming structure, language, compiler, etc for quantum computers, Boolean Algebra is not practical due to what limitation of quantum superposition?

b. [4 pts] What operations in standard digital machine level architecture cannot be used in Quantum state level architecture?

c. [4 pts] What operators allow a quantum state level machine to be used?

32. [2pts] Recently, a new 8 Qubit component chip was announced. The documentation indicates that it uses Majorana sites in a topological superconductor. The Majorana fermion was first proposed in 1934 but has never been observed. What unique property does this potential particle have?

a. It is massless

b. It is its own antiparticle

c. It has a charge of $-1/2$

d. All the above

33. [2 pts] The claimed superiority of this topological superconductor Qubit design is...

a. The speed at which superposition can be established and read

b. The high tolerance to noise due to the Majorana robustness

c. Long stability of the Qubit state

d. All the above

34. [2pts] Bell's theorem disproves realism

a. True

b. False

35. [2pts] How many qubits are involved in Shor's code for quantum error correction? _____

36. An extensively researched quantum storage mechanism is N-V centers in diamond.

a. [2pts] What element does N refer to in this quantum storage mechanism?

a. Nitrogen

b. Neon

c. Nickel

d. Niobium

e. Neptunium

f. Neodymium

b. [2pts] One charge state of the N-V center is NV^0 . NV^0 is paramagnetic which means it is weakly repelled by an external magnetic field

a. True

b. False

c. [2pts] NV^- center can be thought of as a qubit with $m_s = 0$ and $m_s = \pm 1$ states. What type of radiation is shone at the NV center to change the state?

a. X-rays

b. Ultraviolet

c. Visible Light

d. Infrared

e. Microwaves

f. Radio waves

d. [2pts] What type of radiation is used to measure the state of the NV center?

a. X-rays

b. Ultraviolet

c. Visible Light

d. Infrared

e. Microwaves

f. Radio waves