Quantum Quandaries

1. **DESCRIPTION:** Teams will demonstrate an understanding of quantum physics as well as classical physics, including mechanics, statistical physics, and other fields in modern physics such as relativity, particle physics, and condensed matter physics. (For any clarifications/questions, competitors should reach out to saitoy@mit.edu.)

   A TEAM OF UP TO : 2 **APPROXIMATE TIME:** 50 minutes

2. **EVENT PARAMETERS:**
   a. Each team may bring one of the following options containing information in any form and from any source:
      i. a computer/tablet and a three-ring binder; or,
      ii. two computers/tablets, of any kind; or,
      iii. two three-ring binders.
   b. If three-ring binders are used they may be of any size and the information contained should be attached using the available rings. The information or pages may be removed during the event. Sheet protectors and laminated sheets are allowed.
   c. Each team may bring two stand-alone calculators of any type. If the participants are using a computer/tablet they may use the calculator app or other program on their device in place of a stand-alone calculator.
   d. Participants using computers/tablets as a resource should have all information stored so that it is available to them offline.
   e. The Event Supervisor will provide an equation sheet with relevant constants.

3. **THE COMPETITION:**
   The following topics may be tested
   a. Classical Physics
      i. Newtonian mechanics
      ii. Hamiltonian mechanics
      iii. Lagrangian mechanics
      iv. Wave mechanics
         (1) Normal modes
         (2) Wave superposition
         (3) Classical harmonic oscillators
      v. Statistical physics
         (1) Laws of thermodynamics
         (2) Boltzmann distribution, Poisson distribution, binomial distribution, geometric distribution
         (3) Entropy and its relation to temperature and information
         (4) Partition function
         (5) Microcanonical ensemble
         (6) Canonical ensemble
      vi. Relativity
         (1) Special relativity
         (2) Lorentz transformation
         (3) Length contraction
         (4) Time dilation
         (5) Spacetime diagrams
         (6) Gravity
   b. Quantum Physics
      i. Quantum mechanics
         (1) Complex numbers, complex functions, complex conjugation

(2) Wavefunctions, the Born rule, normalization
(3) Double-slit experiment
(4) Photoelectric effect
(5) Compton effect
(6) Uncertainty principle
(7) Free particle
(8) Particle in a box
(9) Quantum harmonic oscillator
(10) Operators, observables, quantum states

ii. Particle Physics
(1) Standard model
(2) Feynman diagrams

c. Mathematics

i. Basic Linear Algebra
(1) Linearly independent bases
(2) Hermiticity

ii. Basic statistics
(1) Expected values
(2) Standard deviation
(3) Various probability distributions and their uses

Note: In terms of math, familiarity with precalculus, addition/multiplication of matrices, addition/multiplication of complex numbers, and basic statistics like computing expected values and standard deviation from probability distribution should be adequate. Knowledge of calculus and more advanced linear algebra may be helpful but is not necessary.

4. **SCORING**:
   a. All questions will have been assigned a predetermined number of points.
   b. The highest score wins.
   c. Selected questions will be used to break ties.

Recommended Resources: All listed resources can be accessed for free.

1. Wikipedia - While it should not be the source of your knowledge, it's a great place to whet your appetite and learn about high level concepts and ideas that exist in the field.
2. Hyperphysics (http://hyperphysics.phy-astr.gsu.edu/hbase/index.html)
3. MIT OpenCourseWare (https://ocw.mit.edu/) (Note: this list is a very thorough reference in case if you want to dive deeper into physics; to prepare for the event, you should be able to pick out topics in each course that are listed in section 3 of the rules.)
   a. 8.01 Classical Mechanics
   b. 8.03 Vibrations and Waves
   c. 8.033 Relativity
   d. 8.044 Statistical Physics I
   e. 8.04 Quantum Physics I
   f. 8.05 Quantum Physics II
   g. 18.05 Introduction to Probability and Statistics
   h. 18.06 Linear Algebra
4. Textbooks/Lecture Notes
   a. The Feynman Lectures on Physics (https://www.feynmanlectures.caltech.edu/)
   b. Quantum Computation and Quantum Information - Michael Nielsen and Isaac Chuang (http://mmrc.amss.cas.cn/tlb/201702/W020170224608149940643.pdf)
   c. Lectures on Dynamics and Relativity - David Tong (http://www.damtp.cam.ac.uk/user/tong/relativity.html)
   d. Lectures on Quantum Mechanics - David Tong (http://www.damtp.cam.ac.uk/user/tong/quantum.html)

e. Lectures on Solid State Physics - David Tong
(http://www.damtp.cam.ac.uk/user/tong/solidstate.html)
f. Lectures on Statistical Physics - David Tong
(http://www.damtp.cam.ac.uk/user/tong/statphys.html)
g. Lectures on Particle Physics - David Tong
(http://www.damtp.cam.ac.uk/user/tong/particle.html)