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Physics Today and Its Future*

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Abstract: Listing more than one hundred unanswered questions the present author claims that 1) the long standing puzzles in physics may be the signals of new physics; 2) the effort of searching for the basic natural laws of physics is always highly worthwhile.

Key words: physics; special relativeity; quantum mechamics

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It is meaningful to review physics today and look into it's future while celebrating the 80th birthday of Prof. L. M. Yang whose 51-years successive activities full of achievements encompassed so many different fields in physics. I write this paper just as a little token of my best wishes for that in the years to come Prof. Yang will be as helpful to physics and our physics community as in the past.

With the bad news of the abandonment of the Superconducting Super Collider, the shutdown of some other large modern experimental equipment and facilities, the slump of the global economy, the slash of the budget for supporting the basic research of physics in some countries, a shortage of physics job, a lot of talented graduate students defected to go into computer science, brain science or commercial circles etc., "has physics come to an end?" has even become a current subject of conversation in international physics community[1~3].

Talk of an impending crisis is not new. The history recorded many such examples but were eventually overcome. The most dramatic crisis periods occurred at least twice in this century. 1) Around the turning point of the nineteenth and twentieth century, it was believed that the great hall of classical physics had been well established by some great physicists: Newton (1642~1727), Maxwell (1831~1879), Clausius (1822~1888), Boltzmann (1844~1906), Gibbs (1839~1903) etc., and that all properties of matters could be understood in terms of classical physics except for two dark clouds in the sky of physics, i. e. the famous Michelson-Morley experiment and black body radiation, as was once said by Kelvin (1824~1907). In fact, it is far from true. Not only all attempts to find a reasonable explanation for Michelson-Morley experiment as well as a satisfactory wave-theory for black body radiation met with failure, but also people failed to understand electrons, protons and what were going on in Röntgen-rays as well as other forms of radiation emanating from atoms. These problems were overcome by the discoveries of special relativity and quantum theory, which are undoubtedly the greatest achievements in physics of this century. 2) In the late 1920s, shortly after

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the discovery of Dirac's equation, Max Born told a group of scientists visiting Göttingen that, "physics, as we know it, will be over in six months[1]". However, the discoveries of neutron and nuclear forces disappointed Born's optimistic inference.

We are now near the end of the twentieth-century. In the past one hundred years physics never came to an end, it has made a lot of progress and has brought a microscopic civilization to us. Now the physics is in a deep trouble. The present crisis is very different from those in the developing history of physics in following aspects: 1) the fundamental research in physics is losing the support of public society since the end of the Cold War era; 2) some new experimental phenomena as well as some long-standing puzzles could not be answered by the established ideas. According to my preliminary consideration more than one hundred unanswered questions and long-standing puzzles in physics are listed below, some of them may be found in Ref[4~ 8]:

1. Are there more than four fundamental interactions in nature?

2. Why do the fundamental physical constants have their present value?

3. Do the constants of nature change very slowly on a cosmic scale?

4. Why would all known dynamic laws be time reversible?

5. Why does time have an arrow and never go backward?

6. Does time really have a beginning and an end?

7. Isn't the cosmological epoch an uniform flow of time?

8. Why does hot water freeze faster than cold water[8]?

9. Are there crystals with an apparent seven-fold axis in nature?

10. When and how is the geomagnetic field started?

11. What is the physical reason about geomagnetic reversals?

12. What is the cause of the Antarctic ozone hole?

13. What is the mechanism for forming a turbulence?

14. How does the earthquake light form before earthquakes?

15. Why is it that lightning are usually zigzag shaped but rarely sphere-like?

16. What do the phenomena of too many μ mesons in Extensive Air Showers imply?

17. Why can the ionosphere keep long-time memory for some processes?

18. Where did the earth come from?

19. What is the origins of life on earth?

20. How does irreversible thermodynamics play a role in the metabolism of life?

21. What is the origin of the irreversibility enshrined within the second law of thermodynamics[9]?

22. What physical meaning does entropy have for open system?

23. How our world evolved from ordered crystal → incommensurate phase → chaos → aperiodic biological system?

24. Can one understand the structure of atomic arrangement in amorphous metal?

25. Can one understand the formation of Schottky barrier on the surface states of metal-semiconductor contacts[10]?

26. Why does the low-dimensional system possess a series of physical phenomena which can't occur in three-dimensional system[11~ 12]?

27. Can the problem of nonlinear elementary exitations in low-dimensional condensed matter be solved[11~ 12]?

28. Can one reveal the secret of lattice relaxation effect?

29. Can we find a unified picture to

comprehensive understanding of nematic liquid crystalline state and its transition into isotropic phase[13]?

30. What is the main mechanism of the beam foil interaction[14]?

31. What is the physical origin of Coriolis attenuation[15]?

32. Does the anomalon really exist[16]?

33. What is the microscopic mechanism of high temperature superconducting?

34. May one get success to use anyon[17, 18] to explain the mechanism of high T_c superconducting?

35. Can the room-temperature superconductors be realized?

36. Can quantum-mechanical description of physical reality be considered complete?

37. Can we prove the Berry's conjecture[19]?

38. What is the relation between geometric phase of quantum system in evolution and guage field as well as basic interactions[20, 21]?

39. Is Schrodinger's cat alive or dead?

40. Can we measure the wave function of a single wave packet of light[22]?

41. Does quantum mechanics contradict relativity according to Bell's theorem?

42. What is the exact physical meaning of quantum chaos?

43. May the completeness criterion of Einstein-Podolsky-Rosen[23] be a possible growing point of tachyon theory?

44. Can tachyon theory be established on the foundation of special relativity[7]?

45. Will the temperature of a moving-body change?

46. Can the paradoxes in special relativity such as the Ehrenfest paradox[24], the pole-vaulter's paradox, the apparent shape paradox of rapidly moving objects, stress effect paradox due to length contraction, upper limit paradox on the proper length, the thread paradox, the right-angled lever paradox, superluminal velocity paradox oppenheimer paradox, and other recently raised problems[7, 25] be solved?

47. What is the essence of thermal neutron radiation capture query?

48. Can the nuclear magnetic moments be accurately evaluated?

49. Are there nuclear reactions inside living organism?

50. Can we solve the question of g_A (bound nucleon) $\neq g_A$ (free nucleon) = 1.25 in Gamow-Teller giant resonance?

51. Can the binding energy and the energy levels of finite nucleus be accurately figured out?

52. Can EMC effect be solved completely?

53. What is the dynamic origin of the proton spin if little of it is carried by the quarks?

54. Can one find the explanation of electron and positron sharp peaks observed in large Z heavy-ion collisions?

55. Can one find the experimental evidence of the so-called yrast trip for rotation nucleus[26]?

56. What is the role of superfluid effects in the tunnelling between the supperdeformed states of the nucleus in high-spin and the normal states of the nucleus at lower angular momentum[27]?

57. What are the collective and statistical mechanism involved in trapping of the nuclear systems in the superdeformed regions of phase space?

58. Why do the Σ hypernuclear states exist with narrow widths?

59. What is the proton-number of the last superheavy element in periodic table?

60. Is the multiphonon transition the main process in the non-radiactive transitions?

61. How do the ultrashort laser light pulses form?

62. Can various nonlinear intense light effects be explained by nonlinear electric polarization effect?

63. Does cold fusion have a future?

64. Can the controlled thermonuclear fusion be realized?

65. Can inertial confinement fusion be realized?

66. Does the quark-gluon plasma (QGP) really exist?

67. Does glue-ball exist?

68. When can we reveal the solar neutrino puzzle?

69. Is the rest mass of the neutrino being non-vanishing?

70. Are there neutrino oscillations in nature?

71. When can we find the neutrinoless double β decay?

72. Considering whole energy range, whether perturbative QCD will really survive as an acceptable candidate for the fundamental theory of strong interaction?

73. Can we demonstrate that confinement is a consequence of QCD?

74. Can we find various cases of CP-violation beyond K^0 weak decays?

75. What is the origin of CP-violation[28]?

76. Are there realistic senarios with large CP effects to create the observed baryon asymmetry[28]?

77. Are the CP asymmetries observed at the laboratory connected to the cosmological CP-violation at the early universe[28]?

78. Can free quarks be discovered in future experiments?

79. When can the myth of e-μ-τ be solved?

80. What is the origin of Higgs mechanism[28]?

81. Where is the Higgs boson with predicted 138 GeV mass[29]?

82. What is the physical meaning of quark-lepton symmetry?

83. Why does the matter in the universe have mass?

84. Does the neutron ↔ anti-neutron oscillations exist in nature?

85. Does the process of d meson ↔ pion exist in nature?

86. Can the puzzle of $\rho\pi$ in $C\Psi$ physics be solved[30]?

87. Does quark (lepton) have a structure?

88. Does the electron have a structure?

89. Does the photon have a structure?

90. How many more elementary objects are there beyond quarks and leptons?

91. Are there any final elementary constituents in nature?

92. Is the baryon number really not conserved?

93. What is the lifetime of a proton?

94. Is the lepton number conservation violated?

95. What are the power engines behind quasars?

96. Does new ether exist?

97. Can the Olber's paradox be solved[7]?

98. What is the origin of the seed of cosmic magnetic field[7]?

99. How big is the cosmological constant?

100. Can gravity be described by a quantized theory?

101. Can gravity and other three interactions be unified?

102. Where is the graviton?

103. Can the gravity be shielded?

104. When can we identify the black holes?

105. What is the physical meaning of Dirac's large number hypothesis[7,31]?

106. Is there a connection between the structure of the universe and the structure of elementary particles?

107. Do the laws of physics as we know them apply on the scale of the universe?

108. How big is the visible universe space?

109. What is the shape of the visible universe?

110. How massive is the visible universe?

111. How long has the visible universe

existed?

112. Does the universe have a beginning and an end in time, and what exactly is time?

113. Will the universe expand forever or eventually collapse back on itself?

114. Why is the portion of the universe that we can see so flat and smooth[32]?

115. What is the origin of the tiny inhomogeneities that seeded the formation of the structure of the visible universe[32]

116. What is the nature of the ubiquitous dark matter that is the dominant component of the mass density[32]?

117. Is the cold dark matter in universe made up of weak interaction massive particle (WIMP) axions and others?

118. Is new matter constantly created in the universe?

119. What is the physical meaning of quadrupole anisotropy in the cosmic microwave background radiation?

120. Can one resolve the difficulties in the study of interstellar medium ^{26}Al?

121. Can we find three kinds of defects in the fabric of space-time-monopoles, cosmic strings and domain walls?

122. How many phase transitions may be occurred in the young vacuum?

123. May the large wormholes really be used as time machines?

124. Can we scale the Planck scale?

125. May the strange stars really exist?

126. May the quark stars really exist?

127. Can physics give some explanation for the initial conditions of universe beyond the anthropic principle?

128. What does a series of cosmic coincidences imply?

129. Is there a basic preference for matter over antimatter in the universe?

130. Does anti-matter universe exist?

131. Does our universe have brothers?

132. Does the wormhole really link our universe and other universes?

133. Do other intelligent civilizations exist?

We see, of course, that not all of the questions as mentioned above are basic problems in physics. Some of them are frontiers, the others are old long-standing puzzles. Obviously, some of them seemed to be related, that is, they have the same physical origin that we do not know right now. In a word, these kinds of gaps mean that our understanding of nature is incomplete. Compared with the pond of known knowledge, our ignorance in physics remains as the Pacific Ocean.

In the following I would like to claim two points. 1) The long standing puzzles in physics may be the signals of new physics; 2) The efforts of searching for the basic natural laws of physics will be always highly worthwhile.

If somebody says "technology equals solutions", I'd cry: basic science equals sources, because the history of the last hundreds years teaches us that physics is the foundation of foundations. I am sure that in 21th century parts of above listed unanswered questions will be solved, new laws of physics will be found and new physics will help human to solve the troubles as mentioned below and bring a more bright future to us.

Firstly, the historical lessons merit attention, physics is endless. In the last three to four hundreds years, the preservation of causality is a prime mover of physics research. The development of physics has proceeded in steps of causal chain, each of which solved the problems at one level by opening another new and deeper level of problems. For instance, in order to clarify the properties of chemical compounds, molecules and atoms were introduced into physics; then nuclei and electrons were introduced to explain the properties of the atom. Again, the problems of nucleons and other new particles led us to the picture of quarks and gluons. In each of causal chains the successor theory to its predecessor theory can be regarded as a causal illustration in a broader range of nature phenomena with a higher precision. Somebody once believed that theory of everything (TOE) might be an ultimate theory in physics[33], the superstring theory[34] with only one parameter was said being one such candidate. Why the unique parameter should take the value it would be? This is an open question in TOE. Therefore, it is an inexorable trend to seek a further theory with a wider domain of applicability than TOE.

Secondly, there are layers of structure in our universe. From the large-scale structure of the universe, clusters of galaxies, galaxies, stars, solar system to the intricate biological systems, clusters of molecules and atoms, simple molecule and atom, nucleons and quarks, according to G. W. F. Hegel's law of mutual change of quality and quantity, there must exist some special laws in aggregates of different size in each layer. The low-dimensional systems possess a series of physical phenomena which can not occur in three-dimensional system; the laws in mesoscopic systems are different from those in macroscopic and microscopic systems; although we already know the physical laws which govern everything that we experience in everyday life, we are still not able to make detailed predictions in any but simplest situation. All are good examples. Besides, how about a lot of categories of new cutting-edge fields which I have not dealt with?

Again, "A person brought somehow to today from only a hundred years ago would find the world very different and even bewildering. Back then the average life span was short, infant mortality was much higher, and disease carried off more people than did old age. Communications were primitive, only crude telephones existed, and there was no radio or television. The average person knew little of the rest of the world. Transportation was slow, and there were no automobiles or airplanes. There was no knowledge of subatomic world, no computers and so on. Indeed, most of the work that people do today is in areas that did not exist back then and is based on the technologies derived from the scientific revolution begun by great physicist Galieo (1564~1642)[35]." Of course, most changes happened in 20th century since human being knew special relativity and quantum theory. It is just that without the progresses in basic research of physics there will be no such achievements in other fields. In a sense, electron spin, fission, thermonuclear fusion, nuclear reactors, nuclear power stations, Tokamak, liquid-crystal, masers, lasers, superconductivity, superfluidity, transistors, computers, cyberculture, internet, World Wide Web (WWW), 3-D virtual environments, autonomous software agents, speech recognition, nanontechenology, scanning tunneling microscopy (STM), remote scanning probe microscopy based on internet, bioengineered pharmaceuticals, DNA gene chips, televisions, digital cameras, virtual video games etc., all of these great discoveries or inventions are, indeed, the inevitable connected with special relativity and quantum theory. In next century, we will be facing food crisis, energy crisis, resource crisis and a lot of troubles such as surplus of global population, pollution, the global warming, ozonosphere hole, planet ' s environment, public health, transportation and new traffic safety, sewage discharge and treatment, municipal refuse treatment, urban storm-water routing, resistance to pests and diseases, how to boost productivity and corporate profits as well as standards of living and so on. Unlimited growth is not possible in a limited world! What shall we do? Where is the way out? In my opinion, it will be the unique correct choice for human kind to ask the basic research of sciences (including physics) to come to the rescue.

In summary, physics will never come to an end. The universe will always remain inexplicable. It will always have mysteries for generation to generation.

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物理学的现状和未来*

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摘　要: 列举了物理学中 100 多个未解决的问题, 阐明物理学中长期悬而未决的难题正是新物理学将要诞生的信号, 人类探索物理学基本规律的努力总是值得的 .

关 键 词: 物理学; 狭义相对论; 量子力学

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