'Physical minimum' — what problems of physics and astrophysics seem now to be especially important and interesting at the beginning of the XXI century? [1]

V L Ginzburg

In recent years I have been placing progressively stronger emphasis, as far as physics is concerned, on some educational program, which I conventionally call the 'physical minimum'. As far as I know, many young scientists attend Nobel Lectures, and therefore I decided to enlarge on this 'physical minimum'.

We in Russia like to quote a certain Koz'ma Prutkov, a fictitious character, who said pompously, in particular, that "there is no way of comprehending the incomprehensible". So, one has to choose something. And so I took this path: I have made a 'list' of the top problems of the day. Any such list is admittedly subjective. It is also clear that the 'list' should vary with time. Lastly, it is clear that subjects not included on the 'list' can in no way be regarded as unimportant or uninteresting. It is simply that many of them presently seem less pressing to me (or to the authors of other similar lists). But again, "one cannot comprehend the incomprehensible." Those who know interesting subjects beyond the 'list' have no reason to be offended and should only supplement or change the 'list'. Acquaintance with all the subjects included on this 'list' is what I call the 'physical minimum'. Of course, this 'minimum' is the echo of the 'theoretical minimum' proposed by Landau in the 1930s. A beginner needs help to get acquainted with the 'physical minimum'. Working out this 'list', as well as commenting on it, has served and hopefully continues to serve precisely this purpose.

On the whole, should the proposal be taken advantage of and elaborated, the 'physical minimum' will meet with support and new books on this subject should appear. Unfortunately, I cannot set myself to this task.

In the context of this lecture it only remains for me to recall the well-known saying that the proof of the pudding is in the eating and give the above-mentioned 'list' for the beginning of the XXI century:

1. **Controlled nuclear fusion.**
2. **High-temperature and room-temperature superconductivity (HTSC and RTSC).**
3. **Metallic hydrogen. Other exotic substances.**
4. **Two-dimensional electron liquid (anomalous Hall effect and other effects).**
5. **Some questions of solid-state physics (heterostructures in semiconductors, quantum wells and dots, metal – dielectric transitions, charge and spin density waves, mesoscopics).**
6. **Second-order and related phase transitions. Some examples of such transitions. Cooling (in particular, laser cooling) to superlow temperatures. Bose – Einstein condensation in gases.**
7. **Surface physics. Clusters.**
8. **Liquid crystals. Ferroelectrics. Ferrotoroics.**
9. **Fullerenes. Nanotubes.**
10. **The behavior of matter in superstrong magnetic fields.**
11. **Nonlinear physics. Turbulence. Solitons. Chaos. Strange attractors.**
12. **X-ray lasers, gamma-ray lasers, superhigh-power lasers.**
13. **Superheavy elements. Exotic nuclei.**
14. **Mass spectrum. Quarks and gluons. Quantum chromodynamics. Quark-gluon plasma.**
15. **Unified theory of weak and electromagnetic interactions. $W^{\pm}$ and Z^0 bosons. Leptons.**
16. **Standard model. Grand unification. Superunification. Proton decay. Neutrino mass. Magnetic monopoles.**
17. **Fundamental length. Particle interaction at high and superhigh energies. Colliders.**
18. **Nonconservation of CP-invariance.**
19. **Nonlinear phenomena in vacuum and in a superstrong electromagnetic fields. Phase transitions in a vacuum.**
20. **Strings. M-theory.**
21. **Experimental verification of the general theory of relativity.**
22. **Gravitational waves and their detection.**
23. **The cosmological problem. Inflation. Λ-term and 'quintessence'. Relationship between cosmology and high-energy physics.**
24. **Neutron stars and pulsars. Supernova stars.**
25. **Black holes. Cosmic strings (?).**
26. **Quasars and galactic nuclei. Formation of galaxies.**
27. **The problem of dark matter (hidden mass) and its detection.**
28. **The origin of superhigh-energy cosmic rays.**
29. **Gamma bursts. Hypernovae.**
30. **Neutrino physics and astronomy. Neutrino oscillations.**

The singling out of 30 particular problems (more precisely, items on the 'list') is of course absolutely conditional. Moreover, some of them might be subdivided. On my first 'list' published in 1971 there were 17 problems. Subsequently, their number would grow. It would supposedly be well to add some new subjects to the 'list', for instance, those concerning quantum computers and advances in optics. But I cannot do this with adequate comprehension.

Any 'list' is undoubtedly not dogma, some things can be discarded and some things added, depending on the preferences of lecturers and authors of corresponding papers.

It should be added that three 'great problems' of modern physics are also to be included in the physical minimum, included in the sense that they should be singled out in some way and specially discussed, and their development should be reviewed.

The 'great problems' are:

First, the increase in entropy, time irreversibility, and the 'time arrow'.

Second is the problem of interpretation of nonrelativistic quantum mechanics and the possibility of learning something new even in the field of its applicability (I personally doubt this possibility but believe that one's eyes should remain open).

And third is the question of the reduction of the animate to the inanimate (line-to-liveless reduction), i.e., the feasibility of explaining the origin of life and thought on the basis of physics alone.

One more concluding remark. In the past century, and even nowadays, one could encounter the opinion that in physics nearly everything had been done. There allegedly are only dim 'cloudlets' in the sky of theory, which will soon be eliminated to give rise to the 'theory of everything'. I consider these views as some kind of blindness. The entire history of physics, as well as the state of present-day physics and, in particular, astrophysics (including cosmology), testifies to the opposite. In my view we are facing a boundless sea of unresolved problems.

It only remains for me to envy the younger members of the audience, who will witness a great deal of new, important, and interesting things.

[1] Presented in this article is an abridged excerpt of Ginzburg's Nobel Lecture. For the full text, see *Phys.-Usp.* **47** (11) 1155 (2004) or (in Russian) http://www.ufn.ru/archive/russian/abstracts/abst3433.html; for several new comments on the 'list', see http://data.ufn.ru//tribune/trib230107.pdf.