

THE NATURE OF PHYSICS PROBLEM-SOLVING

Below are 29 sets of questions that students and physicists need to ask themselves during the research process. The answers at each step allow them to make the 29 decisions needed to solve a physics problem. (Adapted from reference 3.)

A. SELECTION AND PLANNING

1. What is important in the field? Where is the field heading? Are there advances in the field that open new possibilities?

2. Are there opportunities that fit the physicist's expertise? Are there gaps in the field that need solving or opportunities to challenge the status quo and question assumptions in the field? Given experts' capabilities, are there opportunities particularly accessible to them?

3. What are the goals, design criteria, or requirements of the problem solution? What is the scope of the problem? What will be the criteria on which the solution is evaluated?

4. What are the important underlying features or concepts that apply? Which available information is relevant to solving the problem and why? To better identify the important information, create a suitable representation of core ideas.

5. Which predictive frameworks should be used? Decide on the appropriate level of mechanism and structure that the framework needs to be most useful for the problem at hand.

6. How can the problem be narrowed? Formulate specific questions and hypotheses to make the problem more tractable.

7. What are related problems or work that have been seen before? What aspects of their problem-solving process and solutions might be useful?

8. What are some potential solutions? (This decision is based on experience and the results of decisions 3 and 4.)

9. Is the problem plausibly solvable? Is the solution worth pursuing given the difficulties, constraints, risks, and uncertainties?

Decisions 10–15 establish the specifics needed to solve the problem.

10. What approximations or simplifications are appropriate?

11. How can the research problem be decomposed into subproblems? Subproblems are independently solvable pieces with their own subgoals.

12. Which areas of a problem are particularly difficult or uncertain in the solving process? What are acceptable levels of uncertainty with which to proceed at various stages?

13. What information is needed to solve the problem? What approach will be sufficient to test and distinguish between potential solutions?

14. Which among the many competing considerations should be prioritized? Considerations could include the following: What are the most important or most difficult? What are the time, materials, and cost constraints?

15. How can necessary information be obtained? Options include designing and conducting experiments, making observations, talking to experts, consulting the literature, performing calculations, building models, and using simulations. Plans also involve setting milestones and metrics for evaluating progress and considering possible alternative outcomes and paths that may arise during the problem-solving process.

B. ANALYSIS AND CONCLUSIONS

16. Which calculations and data analysis should be done? How should they be carried out?

17. What is the best way to represent and organize available information to provide clarity and insights?

18. Is information valid, reliable, and believable? Is the interpretation unbiased?

19. How does information compare with predictions? As new information is collected, how does it compare with expected results based on the predictive framework?

20. If a result is different from expected, how should one follow up? Does a potential anomaly fit within the acceptable range of predictive frameworks, given their limitations and underlying assumptions and approximations?

21. What are appropriate, justifiable conclusions based on the data?

22. What is the best solution from the candidate solutions? To narrow down the list, decide which of those solutions are consistent with all available information, and which can be rejected. Determine what refinements need to be made to the candidate solutions. For this decision, which should be made repeatedly throughout the problem-solving process, the candidate list need not be narrowed down to a single solution.

23. Are previous decisions about simplifications and predictive frameworks still appropriate in light of new information? Does the chosen predictive framework need to be modified?

24. Is the physicist's relevant knowledge and the current information they have sufficient? Is more information needed, and if so, what is it? Does some information need to be verified?

25. How well is the problem-solving approach working? Does it need to be modified? A physicist should reflect on their strategy by evaluating progress toward the solution and possibly revising their goals.

26. How good is the chosen solution? After selecting one from the candidate solutions and reflecting on it, does it make sense and pass discipline-specific tests for solutions to the problem? How might it fail?

Decisions 27–29 are about the significance of the work and how to communicate the results.

27. What are the broader implications of the results? Over what range of contexts does the solution apply? What outstanding problems in the field might it solve? What novel predictions can it enable? How and why might the solution be seen as interesting to a broader community?

28. Who is the audience for the work? What are the audience's important characteristics?

29. What is the best way to present the work to have it understood and to have its correctness and importance appreciated? How can a compelling story be made of the work?