Notes on the term paper*

- *You are to write a critical essay of about 3300 – 5000 words* (10-15 typed pages) on some aspect of the interpretation of physical theories. The topic should reflect your interests and make use of your background. You should develop your topic into a coherent presentation of ideas for which you argue clearly and convincingly. We do not expect you to do groundbreaking work on the foundations of science, but you must not merely summarize or restate some other author's views.

WARNING

IT IS AN UNFORTUNATE HISTORICAL FACT THAT PEOPLE TEND TO PUT OFF THEIR TERM PAPER WORK UNTIL TOO LATE IN THE TERM TO DO A GOOD JOB. NOTE CAREFULLY THE SCHEDULE DESCRIBED BELOW.

- *Finding a topic that interests you and that is reasonably accessible is the most important step in writing the term paper.* See below for suggestions on topics. One good approach is to write an in-depth critical response to one or several recent works on the interpretation of physics. It's a good idea to make a trip to a bookstore soon to find some work you're interested in. You can then read it and plan out your paper in parallel with the rest of the course. It's not very practical to wait until the course has dealt with some topic to find out whether you want to write about it, especially since some of the most fascinating material is reached only in the last month. Of course, we hope that what's said in the course will be of use to you in deciding what you want to write about for your topic. If you have any doubt about whether your proposed topic is "viable", you are strongly urged to contact the instructor and/ or TAs at an early stage. In any case, you should meet with Professor Leggett before submitting a topic; ***there will be a 10% penalty for the final term paper grade for failure to consult with him at least once in the writing of the paper.***

  You must *choose a topic*, and submit a tentative topic paragraph and list of the main references, by ***October 10*** (mandatory).

- An *outline with topic paragraphs* is due ***October 24*** (mandatory). You should write an introductory paragraph for each of the two or three major sections of your paper. Unlike other assignments, the outlines must be revised until they are acceptable. It is better to spend an extra round of work finding

* The following applies only to undergraduate students. Any graduate students taking the course for credit should see the instructor individually for guidance as to what is required.

a good topic and approach at this early stage than to waste time writing a dead-end paper. At least one post-outline consultation with the instructor must be held while the paper is being written. ***There will be a 10% late penalty for the final term paper grade for failure to submit an outline by the due-date.***

- The *first complete draft* is due on ***November 14***. (Submission of the first draft is strongly encouraged but not mandatory) Initial comments will be made, on a first-come, first-serve basis, by ***November 22***.

- The *final revised paper* is due by class time on the last day of class – Tuesday, ***December 12***. No late submission will be accepted (unless you have a written medical excuse).

Approaches to the paper include:

1. Write a critical essay on some recent or well known work concerning the meaning of physics. Since one can often come up with intelligent criticisms and supporting arguments for new works, yet there are no standard texts providing such arguments, these critical essays offer a good opportunity to do original, but not groundbreaking work.

   E.g.: Numerous attempts have been made to popularize some to the philosophical implications of quantum physics, including *The Tao of Physics*, *The Dancing Wu-Li Masters*, and, to some extent, Herbert's *Quantum Reality*. Examine whether the actual problems of the theory are well represented in these books and whether the broader implications proposed are valid.

   E.g.: Various recent books, mostly by non-scientists, have proposed major re-visions of the standard view of the relation of physics and other sciences to reality. Examine whether these give a reasonable interpretation of the history and practice of physics.

2. Explain the inner logic of some difficult scientific transition.

   E.g.: The rejection of classical space and time rested on a series of experiments which ruled out various alternatives to Einstein's approach. Explain what the alternate views were and how they were eliminated.

3. Examine the history of some major scientific transition.

   E.g.: T.S. Kuhn has proposed a general outline for major scientific "paradigm changes" in *The Structure of Scientific Revolutions*. Examine how well the theory describes one of the major upheavals

covered in this course, or a related one.

E.g.: How did the laws of thermodynamics develop? What were the roles of engineering, physics, economics, etc.?

E.g.: How did ideas about electricity develop in the early 19th century? What role did the prior Newtonian framework play?

4. Examine the interplay between philosophy and physics at some important juncture.

   E.g.: Compare and contrast the views of Descartes, Newton; and Leibniz on the nature of space. How did their views tie in with other aspects of their philosophy and physics?

   E.g.: What role did "pragmatism", "logical positivism", "existentialism", etc., play in setting the stage for the Copenhagen interpretation of QM?

5. Explicate some thorny question of interpretation.

   E.g.: The existence of observations which violate Bell's inequality requires some deep revision of either local causality, induction, realism, or logic. Trace how (or if) realism is violated in any of the accounts of the experimental results.

   E.g.: Einstein and Infeld claim that it is a matter of pure convention whether one adopts the Copernican or Tychonean system. Examine the extent to which that claim is true. (Best for the mathematically inclined.)

   E.g.: One of the most universal laws of physics is that entropy always increases. Yet the definition of entropy is disturbingly subjective. Examine Bayesian or other approaches to making a consistent account of entropy.

   E.g.: What's the evidence for the proposition that space is non-Euclidean? What are the alternative hypotheses?

Note: Any proposed topic that consists simply of a noun without any explicit or implied question (e.g., "The History of Electromagnetism in the Nineteenth Century") will be automatically rejected.

General guidelines (by M. Weissman)

In preparing this guideline, I have borrowed liberally from a paper by G.T. Hole [APA *Newsletter on Teaching Philosophy*, 4, 4 (1984)] available as a handout from the Philosophy Department. However, I have changed the emphasis, since papers for 419 involve much more specific reliance on an external body of knowledge than do the more introspective papers described by Hole.

I cannot emphasize too strongly that these papers should *not* be mere "reports", in which you put together information or views from some sources and transmit them to the reader. Likewise, the papers should not be mere opinion and speculation. The papers for this course should involve some independent critical thinking.

The topics, therefore, should be picked so as to be not too far over your head. Although a paper which uncritically but carefully *explains* the standard view of some difficult issues would be acceptable, but not optimal, a paper which simply collates phrases on some such issue would not.

Some of the most attractive topics would involve applying what you have learned in this course to current questions of the general culture. For example, how would the procedures by which we have evaluated hypotheses work if applied to questions of cold fusion, paranormal effects, or creationism? To what extent does the history of physics support or refute ideas about the cultural relativity of hypotheses? etc.

In most papers the section presenting the physics *per se* should be brief. Usually there is not much new to say on that. Aspects of the interpretation, history, and metaphorical uses of the physics are more likely to raise problems worth discussing in these papers.

Your paper should begin by *identifying the issue* which you will address. The reader does not need to know immediately what you will conclude, but he does need to know the topic. The topic cannot be simply some noun (e.g., "spacetime"), but must be some question or assertion (e.g., "Is space-time geometry purely a matter of convention?")

Most topics will require a section explaining the meaning of the question. Perhaps, if you are writing a critical essay on someone else's work, this section would provide a simple description of that work. If you are writing about some problem in interpretation of an unfamiliar phenomenon, this section would simply describe the phenomenon.

You will then wish to explain why the topic is interesting, e.g., why the views described are controversial, or why the phenomenon seems paradoxical. A set of possible alternate views might be presented, relying somewhat on published literature.

At this point, you will be prepared to start actually reasoning about your topic. Are there obvious logical contradictions in any of the views you have introduced? Are there empirical data that rule out some of the views? Are

there other considerations (historical analogies, partially relevant data, Occam's razor...) that can be found to strengthen or weaken the cases for these views?

Finally, you can wrap up the paper with some conclusions. What ideas are definitely wrong? Are any definitely right? What sorts of developments can resolve the remaining questions? Are further experiments or calculations called for?

Most Important:

After the paper is written and typed, go over it with a hostile attitude, as if someone else had written it. Would you believe any of it if someone else had written it? Would you bother to finish reading it? What parts are impossible to follow? What parts don't make sense? Which of the words on page 9 contradict words on page 3? Do the conclusions have any connection whatever with the pages of detailed physical description at the start of the paper? If not, why are those pages there? What obvious gaps loom? How would the conclusions cease to make sense if applied to slightly different situations?

If possible, it then helps to trade papers with someone else,[†] so you can each find flaws which you overlooked in your own. Then go through the revision process again. You may then add connecting material, auxiliary arguments, clarifications of terms, concessions of limitations, etc. You may take out any digressions and falsehoods.

Do not rely excessively on revising your paper after comments from the instructor. By that point in the semester, you are likely to have other urgent tasks.

[†] If you are a science major, you may find it particularly helpful to pair off with an arts major, and vice-versa.