Essay Plan

Title: [Indicate here the title you have chosen]

It is worth asking yourself *why* you have chosen this title. Remember that , although I hope you will find this task interesting and educational, one of *your* aims must be to ensure that you get a good mark! Sadly, the most interesting title might not be the one that's easiest to write up – you need to balance interest against expediency here.

List of main sources

List the sources that you have already identified as useful for your essay. In each case, note down:

- the full formal reference for the source;
- why you think it is appropriate and reliable (including whether or not it is a primary, i.e. original research, source);
- what you are going to use it for.

For example, a student doing an essay on "The Use of Cepheid Variables in Distance Measurement from Henrietta Leavitt to the HST" would probably include the following entry:

- Henrietta Leavitt (1912), *Harvard College Observatory Circular* **173**, 1.
- Primary source – original research paper. Discovery paper for Cepheid period-luminosity relation.
- Use in the Introduction to motivate usefulness of Cepheids as distance indicators. May include figure showing Leavitt's P-L relation.

The purpose of doing this is to confirm that you have enough good material to base an essay on. If you cannot find half a dozen decent sources, you are going to struggle to avoid plagiarism.

If your essay topic relates to the 19th or 20th century, you should be concerned if your list of sources includes no original research papers. Part of the purpose of this exercise is to allow you to demonstrate that you can use the research literature, and if you have no research papers on your list you have failed to do this. Try searching ADS (http://adsabs.harvard.edu/abstract_service.html) with the key word(s) from the essay title in the "Title" or "Abstract" selection boxes (or, if you're doing a biographical topic, the name of the individual in the "Author" box) and an appropriate range of dates.

If your topic comes from before 1700, you are obviously *not* going to consult original works (they are rare books, and they are in Latin, Greek, Assyrian, Sanskrit or some other unhelpful language). "Primary sources" in this case would include modern translations of the original works, and also papers on the history of astronomy (our library carries the *Journal of the History of Astronomy*), but you would also be justified in relying on specialist textbooks such as Otto Neugebauer's *History of Ancient Mathematical Astronomy*.

The 18th century falls between the two extremes. Some original papers may be accessible (the Western Bank library has an incomplete run of the *Philosophical Transactions of the Royal Society*), but others may not, and you may find the language more difficult to understand.

Outline Plan

Once you are satisfied that you have enough material, start by making an outline plan of your essay. This should include the main subheadings and brief notes about the contents of each section and the sources that will be used. A typical outline plan takes up about half a page of A4 – certainly no more than one page.

Example: our student writing on Cepheid variables might produce the following plan.

1. *Introduction*: the challenge of distance determination in astronomy; the Cepheid period-luminosity relation; brief summary of topics to be covered in body of essay. Source: Leavitt plus general astronomy text.
2. *The Early Years*: early applications of Cepheid variables – the structure of our Galaxy, the distances of Local Group galaxies, the Hubble relation. Sources: Shapley 1918, Hubble 1929, Hubble and Humason 1931.

3. *Two Populations*: Baade's discovery of two stellar populations and subsequent realisation that there are different populations of Cepheids. Effect on Hubble relation. Sources: various papers from 1950s, e.g. Weaver 1954, Reddish 1955, Baade 1956 – search ADS for "period luminosity" or "Cepheid" in title – also review article in *PASP* by Fernie (1969).
4. *Classical Cepheids as distance indicators*: covering work from 1960 on – colour dependence, modelling of masses, use in determining Hubble constant, discrepancies between de Vaucouleurs and Sandage/Tammann, etc. Precise sources and topics to be decided – depends on word count so far!
5. *The HST era*: *classical Cepheids as calibration*. Cepheids in Virgo cluster. The Hubble Key Project. Sources: Hubble Key Project papers (Freedman et al.).
6. *Conclusions*: major achievements of Cepheid distances (status of external galaxies, Hubble's law, contributions to theories of stellar evolution); change in status of Cepheids (from long-range distance indicators through intermediate-range to present status as calibrators for other methods).

A plan like this will give you a feel for whether you have the material you need (this student certainly does, since a page on each of her 6 sections would give her the 3000 words), and whether you can tell a coherent story (you may realise at this point that you don't have the background information you want for your introduction, or that you haven't thought through what your conclusion should be). It will probably also have enlarged your list of sources: as you think more carefully about what you want to include, you will probably find that your initial list is insufficient.

Please feel free to come and discuss your outline plan with me, especially if you are not certain whether you have covered all the necessary material, or if you feel that your source list is looking a bit thin. It is much less work to fix structural problems at this stage than it is when they have been carried all the way through to a draft of the whole essay.

Detailed Plan

At this point you have a clear idea of the structure and content of your essay, and a list of the sources you are going to use to write it. If you are confident in your essay-writing skills, you may now have enough to start writing. However, for most people, it is useful to go one level further down, producing a detailed plan which sets out what you want to say almost paragraph by paragraph. This helps to ensure that your coverage of the topic is balanced, that you do not contradict yourself, and that you use the information in your sources to tell a coherent, well integrated story.

Example: section 1 of the outline plan above might be expanded as follows:

Introduction: Astronomical Distances and the Role of Cepheid Variables

- Importance of distance in astronomy, e.g. knowing absolute luminosity, size etc.
- Basic geometrical method: parallax (Bessel 1838). Very limited range, especially with early 20th century technology.
- Secondary methods: use of proper motion (secular and statistical parallax). Range still quite limited, and intrinsic uncertainties large. After Russell 1913, potential for using main-sequence fitting, but again rather large scatter. Dynamics of visual binaries can also be used, but need suitable system, decent orbit, etc. Therefore, at beginning of 20th century, *no* reliable way of determining distances beyond solar neighbour-hood, leaving many important questions (size of Milky Way, status of spiral nebulae etc.) unanswerable.
- Leavitt 1912: shows that 25 variable stars in SMC have clear linear relation between m_{pg} and log P. As SMC is small, this is a real relation between M_{pg} and log P, i.e. distance modulus is same for each star. If the absolute magnitude of any variable of this class can be determined, clearly this relationship can be used to read off absolute magnitudes, and hence determine distances.
  Show Leavitt's PL relation as figure 1
- Necessary calibration, using Galactic Cepheids, first attempted by Hertzsprung (1913) – statistical parallax of 13 Galactic Cepheids with known proper motions. Similar calibrations also carried out by Russell (1913) and Shapley (1918), who then used "Cepheids" (he included RR Lyrae stars in this class) to study the structure of the Milky Way. This work established Cepheids as long-range distance indicator.
- Hubble (1929) relied heavily on Cepheid distances to discover the velocity-distance relation for "nebulae" (= galaxies). First major contribution of Cepheids to astronomy/cosmology. However, actual value very wrong because of incorrect calibration (confusion of Cepheid types, failure to account for interstellar absorption, and inaccurate proper motions all contributed to this).

- Cepheids have played a key role in extragalactic distance determination ever since – most recently as the principal calibration for the famous Hubble Key Project on the determination of H_0.
- Finally, brief summary of structure of paper: "In this essay, I aim to present the history of the use of Cepheids in distance determination from their discovery to the present day. The early work on Galactic structure and the Hubble relation is presented in Section 2. Section 3 details the revision of the Cepheid calibration following Baade's recognition of the difference between Population I and Population II, while Section 4 considers the later 20th century and the contribution of Cepheids to the notorious "Hubble Wars". The modern use of Cepheids as calibration indicators is discussed in Section 5. Finally, Section 6 presents a summary and conclusions."

At this point, writing the actual text as it will appear in the finished essay should be fairly straightforward, as you now know *exactly* what you want to say. The main challenges remaining are all to do with your communications skills: can you integrate the material from different sources into a single smooth narrative which does not show the joins (the only way the reader should be able to tell that two facts came from different sources is by way of your reference citations!); can you explain the material clearly; can you write good, grammatical formal English; can you *avoid plagiarism*?

As with the outline plan, if you have any doubts about whether you are doing the right thing, you should come and discuss it with me (or with one of the other astronomy lecturers if you prefer). Repairs made at this stage will not show in the final essay, whereas corrections made to a full draft are often obvious in the finished product.

The next step: producing a first draft

Even if you are working from a detailed plan, you should *not* assume that the essay you come up with is the finished product. *You should always regard the first complete version of your essay as a* ***draft.*** I don't think anybody can produce their best possible work at the first go – certainly professional writers don't even try to do so. You will almost certainly be able to improve your essay significantly by checking, correcting and polishing your first draft.

What to do with your draft essay

1. Read it all the way through in one go. Check for balance – are any of the sections over- or under-emphasised compared to the others? Does the conclusion properly reflect the introduction (if you said in your introduction that you were going to demonstrate the importance of Cepheid distances in the history of 20th century astronomy, your conclusion should show that Cepheid distances have been important in the history of 20th century astronomy!)? Does it flow well? Are there any points where you repeat yourself, or (even worse) contradict yourself? Do the topics appear in the right order?

2. Assuming that there are no big structural problems, read it through again, this time *carefully and in detail*. Look for:
   - missing citations to references (every piece of information should have a clearly cited source);
   - missing figure credits (there should be a reference to the source of the figure *in the figure caption* – not just in the text where the figure is discussed);
   - typos, misprints, layout errors (e.g. a heading on its own at the foot of a page, or a figure separated from its caption), accidental font changes (e.g. headings start out bold but later become italic), missing or duplicated figure or section numbers, etc.;
   - poor English, especially problems with punctuation, sentences that don't contain verbs, inappropriate capital letters (a favourite trick played by Word is to capitalise the first word after a displayed equation, even though it's a continuation of the same sentence: "Ohm's law is $V = IR$, Where I is the current and R is the resistance." This needs to be stamped out!), overcomplicated sentences that have lost their way in the middle somewhere, and so on;
   - spelling mistakes that the spell-checker will not spot, such as "there" for "their", missing or unwanted apostrophes, and misspelt proper names ("Russel" for Russell, all sorts of things for Hertzsprung!).

3. Get someone else to read it, preferably someone approximating to the target audience of non-specialist scientists – ideally another student in your year who isn't doing PHY324, or who is doing PHY324 but has chosen a different essay topic. They will be able to tell you if your explanations are unclear or if you have misjudged the level. They will also be much better at spotting typos than you will be – when you read your own work, you tend to see what you intended to write, not what's actually there!
4. Check the reference list. Make sure that all the cited references are there (especially if you are using the (name, date) style of referencing, where it's easy to miss one out) and are properly listed with all the necessary information. If there are references to websites, the last thing you should do before you hand your essay in is to check that all the URLs you quote actually work (you haven't mistyped them, and they haven't suddenly disappeared), and that they do go to the page you actually used (not to the home page of a large site like nature.com or nasa.gov, which really isn't much help).

At this point, I would rather you did *not* ask me for advice, because it puts me in an awkward position: this is assessed work, so I should be marking *your* work, not your work as extensively corrected by me! I worry that I will either do too much of the work for you, or short-change you by failing to point out errors (especially English errors) that I will later mark you down for. If you want input from an academic, I would prefer that you ask one of the other astronomy lecturers, or indeed one of the physics lecturers (as the intended audience is non-specialist scientists, it shouldn't matter that they don't know any astronomy). However, it is better to get the academic input at an earlier stage (outline plan or detailed plan), so that it can be properly integrated into the structure of the essay. If your concerns are primarily with your written English, consult the Writing Advisory Service – that's what it's there for.