Physics 81 Exam 1

Administered 2/24/05 50 points Name: Official Solutions

1. Just last week, I was walking to work in the morning and I saw the town's sidewalk plow just ahead of me, spreading sand on the sheet of icy snow that was completely covering the sidewalk. The sand greatly improved my traction.

   It was a sunny day but quite cold, yet when I returned home in the early evening, I found that the footing was once again treacherous. The sand had melted into the icy snow, and was no longer above the surface.

   Based on the principles we've discussed in class, explain why the sand had melted in, while the ice around it remained. The sand was just plain old sand (no salt mixed in) and was quite cold when it was applied.

   There are two possible causes of this phenomenon. First (and by far the most important) is the albedo of sand vs. snow. The sand is dark and absorbs much more of the incoming sunlight, causing it to warm. The snow reflects nearly all incoming light, thereby staying cold. Secondly, the specific heat of sand is lower than that of ice, so it will warm more for a given energy input.

2. In the appendix of Philander's book, he shows that the addition of a layer of glass doubles the amount of radiation received by the surface of the earth, relative to a planet with no atmosphere. As a consequence, the amount of radiation that the earth emits also doubles and we conclude that the temperature of the earth must be higher. Now tell me...

   (a) If the temperature of the earth is T_o without the glass, what is the temperature with the glass?

   First, remember that if the flux of energy into the earth's surface doubles, the flux of energy out of the surface must double.

   Next, take the relation we have for blackbody radiation...

   $$Q = \sigma T^4$$

   and solve for T:

   $$T = \sqrt[4]{\frac{Q}{\sigma}}$$

   You immediately see that if Q goes to 2, then T must go to $\sqrt[4]{2}T$. So, the answer is $T = 1.19T_o$.

   (b) If the sun is delivering an energy flux S to the earth, and the earth's albedo is 0.3, what will be the flux radiated by the earth's surface when a layer of glass is in place? (As usual, you can assume that the glass is completely transparent to solar radiation and completely opaque to infrared radiation coming from the earth).

   Since the earth is only absorbing $0.7S$, the top of the glass must also radiate $0.7S$. If the top of the glass is radiating $0.7S$, the bottom must also radiate $0.7S$. This means that the earth is receiving $0.7S$ from the sun and $0.7S$ from the glass. Therefore, it must radiate $1.4S$.

3. Imagine you are working at an accelerator mass spectrometry lab in which radiocarbon dates of materials are made. A noted archeologist gives you a tiny piece of charcoal that came from a firepit in South America. She tells you that if the sample is greater than 20,000 years old, it will prove that South America was not colonized by Asians migrating across the land bridge in the Bering Sea and down through North America.

   You estimate that the tiny fragment contains 0.01g of carbon (which is equivalent to 5×10^{20} atoms of carbon) and you know that your mass spectrometer needs at least 5×10^7 atoms of ^{14}C present in a sample to get a reliable date.

   Will you be able to tell the archeologist whether her sample is more than 20,000 years old, with any certainty?

   > Given the size of the sample initially, and the fraction of carbon atoms that are ^{14}C initially (1 in 10^{12}), you can conclude that when the wood was cut down and thrown in the fire, that $0.01g$ chunk had only 5×10^8 atoms of ^{14}C present. After 20,000 years, the number present would be given by
   >
   > $$N = N_o e^{-\lambda t} = 5 \times 10^8 e^{-1.21 \times 10^{-4} \times 20{,}000} = 4.4 \times 10^7$$
   >
   > This is not quite enough carbon to give a good age estimate, and you certainly wouldn't have enough to say if the sample was older than 20,000 yrs.

   Be sure to justify your answer mathematically. You may find it helpful to know that in a living tree today, 1 carbon atom out of every 10^{12} is ^{14}C. In addition, the decay rate (λ) of ^{14}C is $1.21 \times 10^{-4}/yr$, corresponding to a half-life of 5730 years.

4. Philander makes the point that many processes in the natural world exhibit exponential growth. When considering a process that may have a major impact on our society, why is it very important to know our location on the growth curve?

   > The relevant feature of the exponential growth curve is that *growth* is slow initially, and much more rapid later. Thus, if a harmful process is well along in the growth curve and we fail to address it, it will be a very big problem in a very short time.

5. Imagine that Governor Baldacci has just proposed pouring a lot of money into a new center for paleoclimate reconstruction at Bowdoin. 3 different politicians make the following statments in reaction to his proposal.

   (a) This is a poor use of money. Climate change in the future is our concern, so we should be pouring all available resources into a new center for climate modelling that will have predictive capabilities.

   (b) I approve of funding such a center, but I think it's also very important to spell out now, in law, the steps that we should take to head off future climate change. Too often, the mitigation strategies that we use to start addressing a problem are abandoned soon after implementation.

   (c) I support the establishment of this center. The data and scientific insight that will result from its work will go a long way toward removing the politics from our future climate change policy.

Do you agree with any of them (either partially or completely)? If so, which one(s), and why? Your answer should be justified, and informed by the ideas that we have covered in this class.

I would both disagree and agree with parts of every statement. Politician **a** fails to recognize that the the only way to gain insight into the climate system is to examine how it has responded to past perturbations. On the other hand, **a** is correct that predictive climate modelling needs to be addressed as well.

b sees the value in paleoclimate research, but fails to recognize that legislation needs to evolve as more information comes to light. Philander draws a parallel between successful management strategies and the scientific method: hypothesize, compare with expectations, and adjust the hypothesis. Anne Hayden gave a specific example ofthis when she pointed out that fisheries management was initially driven by bad scientific input.

Finally, while **c** is correct that more data will probably lead to better decision making, **c** is somewhat naíve in his/her belief that it will take politics out of the process. Climate change, and climate change policy has such an enormous impact on people that all decisions are bound to be subjective and political.

6. **Bonus Question (your chance to have fun):** What is a quagga? If you don't know, take a guess! Creativity will be suitably rewarded.

First, if you didn't write down something here, you should have. I give points on bonus questions for just about anything you can come up with.

I got lots of interesting responses built around quarks, quanta and quagmires (separately and together), but one of you actually knew that a quagga is a South African animal (now extinct) that looked like a cross between an zebra and a donkey. Quaggas had striped heads and necks, and tawny bodies. They were in the horse family (*Equus quagga*)