

*The first three questions all come to the same point. It is interesting that 50% of you found the same issue. This is a problem perhaps with Griffith's slick style.*

QUESTION 2. Why does Griffiths include the fact that advanced potentials also satisfy the inhomogeneous wave equation? Does that mean that problems can be solved with the advanced potential, or is he just saying "Hey this is neat"?

QUESTION Griffiths mentions that the d'alambertian is time reversal invariant and does not distinguish past from future. We choose the retarded time solutions because they obey the principle of causality. That is all well and good, but why does he bring the advance time solutions up at all. He briefly mentions that there is some theoretical interest to the advance time solutions, but doesn't really say why. If there is no physical significance to the advance time solutions, then what is the theoretical interest?

QUESTION

On page 423 Griffiths gives a heuristic argument for the equations of the retarded potential. If I understand him, the idea is that the potential at a given point and time is equal to the potential at an earlier time. This is because electromagnetic information travels at the speed of light. However, Griffiths then goes on to say that the same argument does not apply to the equations for the electric and magnetic fields. Could you expound on why this is the case? I would think that one way to describe the changing fields at a given point and time is to say that they are equal to the fields at an earlier point and time.

ANSWER: If we find  $V$  and  $\vec{A}$ , we have found  $\vec{B}$  and  $\vec{E}$  that satisfy Maxwell's equations. Through all this, one must remember that though this discussion of retarded time is very helpful in understanding what we are doing, our motivation is NOT to come up with a solution that satisfies some instinctive model, but rather to use our instinct to find a solution to Maxwell's equations. Thus we should not be concerned if the logic of retarded time is a bit strange or inconsistent. The model is only valid because it eventually leads to fields that satisfy Maxwell's equations for time-dependent potentials. Note that this same model DOES not lead to the correct fields (note inequalities on the bottom of 423.)

QUESTION: 1) On page 421, Griffiths remarks that the scalar potential is determined by the charge distribution "right now", whereas the electric field changes only after "sufficient time has elapsed". What is considered a "sufficient" amount of time? It seems strange to say the potential and electric field have different time dependences since they are related to each other. Can you try to explain this more clearly?

ANSWER: We must remember that nothing can move faster than the speed of light. Thus if a charge moves from point  $x = 1$  cm to  $x = 2$  cm, an object  $10^{10}$  cm away can not have its field change for at least .33 seconds. Those interested in astronomy are really used to this idea.

QUESTION: 2) Do gauge transformations serve a purpose other than cleaning up the math? Under what circumstances would we use the Coulomb gauge versus the Lorentz gauge?

ANSWER: Good question! In this class we assume that we just are cleaning up the math. In many cases the Coulomb and Lorentz gauge are equivalent (try for yourself to figure out

when.) In problems with relativity, the Lorentz gauge is often, but not always, the easier to deal with. We will see as we go along which gauge is more appropriate and when. In theoretical physics, gauge invariance becomes a motivation for a theory: For example, we could come up with Maxwell's equations by requiring a theory with gauge invariance. For this reason, physicists often look for new theories of interactions by requiring some sort of gauge invariance.

QUESTION: 3) The explanation on pages 429-430 that only one retarded point contributes to the potentials at any given moment seems unclear to me. What does this mean?

ANSWER: What this means is if you look at a point a distance  $r$  away, you are looking back in time a time  $c/r$ .

QUESTION: Along the same lines, Griffiths says on page 430 that no charged particle can travel at the speed of light, and on page 429 the equation for retarded time indicates that "news" travels at the speed of light. Why is that? I have never really understood how we can distinguish between "information" and "particles" because it seems to me that particles must have some inherent information. If they don't hold some information, how do they behave in certain patterns that we can model? Hopefully you can clear this up for me!

ANSWER: Information is a really tricky concept that I am not sure I am able to clear up for you. The important thing associated with information is that it involves a discontinuous function in time.

thus a sudden disturbance can not propagate faster than the speed of light. The position of a point particle is described by a non-analytic function (a delta function) and thus can not propagate faster than  $c$ . See the answer to the first question as well, it is important.

QUESTION: 1. I think this one is probably trivial, but I've had some problems with things like this for a while. On page 424 he says right after Equation 10.21 that the gradient of  $(\text{cursive})r$  equals  $(\text{cursive})\hat{r}$ . I guess this must be intuitively obvious to most people but I don't know how he got that. Can you shed some light?

ANSWER: Remember  $(\text{cursive } \vec{r}) = \vec{r} - \vec{r}'$  so that

$$\begin{aligned} \vec{\nabla}(|\vec{r} - \vec{r}'|) &= (\partial_x, \partial_y, \partial_z)[(x - x')^2 + (y - y')^2 + (z - z')^2]^{1/2} \\ &= \frac{1}{[(x - x')^2 + (y - y')^2 + (z - z')^2]^{1/2}} (x - x', y - y', z - z') \\ &= \frac{\vec{r} - \vec{r}'}{|\vec{r} - \vec{r}'|} \end{aligned}$$

QUESTION: 3. In example 10.2, he starts out solving the problem by saying that the wire is presumably electrically neutral, and thus the scalar potential is zero. I didn't make that connection. Why did he?

QUESTION: In ex. 10.2, the sentence "the line is presumably electrically neutral so the scalar potential is zero." What exactly is the reasoning behind that?

ANSWER: Unless a wire is somehow given an extra charge, the excess charge is usually

zero in a current carrying wire. Because the problem did not mention a charge being added, one should assume the usual case.

QUESTION: I actually didn't have any questions over these sections. There was a lot to cover, but the math was pretty straight forward.

ANSWER: You may find questions arrive when you actually try to solve problems.

QUESTION: Why can no charged particle travel at  $c$ ? I don't recall reading that before in Griffiths.

ANSWER: It is impossible in the context of special relativity. As we shall see, as you add more and more energy to a particle, it moves closer to the speed of light, but can never exceed it. We will go over this in chapter 12.

QUESTION

In AMO, Dr Abraham used the coulomb gauge, which he also called the radiation gauge. He said that it was useful for situations where no charges are present, ie  $V=0$  and  $\text{Div}(\vec{A})=0$ . This simplifies eq 10.11 since the right hand side goes to 0. Is the coulomb gauge really useful for any other situations? eq 10.11 looks like a bear in general. Is the radiation gauge a special case of the coulomb gauge with  $v=0$ , or is it just another name for the coulomb in general?

ANSWER: I believe the radiation gauge is just another name for the Coulomb gauge. For electrostatics ( $V$  independent of  $t$ ) both the Coulomb gauge and the Lorentz gauge reduce to the same thing, that is  $\vec{\nabla} \cdot \vec{A} = 0$ . When we have a time-dependent potential, the Lorentz and Coulomb gauge are distinct and in some radiation problems, it is enough to just know  $V$ . Since it is often easier to calculate  $V$  if we assume  $\vec{\nabla} \cdot \vec{A}$  is zero, we use the Coulomb gauge in some time-dependent radiation problems.