Write down Maxwell's Equations in simple dielectric media using the complex amplitude form of **E** and **H** starting from

$$\nabla \times \mathcal{H} = \epsilon \frac{\partial \mathcal{E}}{\partial t}$$
$$\nabla \times \mathcal{E} = -\mu \frac{\partial \mathcal{H}}{\partial t}$$
$$\nabla \cdot \mathcal{E} = 0$$
$$\nabla \cdot \mathcal{H} = 0.$$

$$\nabla \times \mathbf{H} = j\omega\epsilon\mathbf{E} = -i\omega\epsilon E$$
$$\nabla \times \mathbf{E} = -j\omega\mu\mathbf{H} = i\omega\mu H$$
$$\nabla \cdot \mathbf{E} = 0$$
$$\nabla \cdot \mathbf{H} = 0.$$

Find a wave equation for the complex amplitude form of **E** and **H** from your results of question 1 $\nabla \times (\nabla \times \vec{U}) = \nabla(\nabla \cdot \vec{U}) - \nabla^2 \vec{U}$

$$\nabla^2 \vec{E} + \frac{\omega^2}{c^2} \vec{E} = 0$$

PHYS 408 Group Activities for Jan 11 2011

Please complete these exercises without opening the textbook. If you have questions talk with your group mates or raise your hand and Ellen or David will come to help

1. The flow of electromagnetic energy is given by the Poynting Vector ($\vec{\mathcal{S}} = \vec{\mathcal{E}} \times \vec{\mathcal{H}}$) Give at least two qualitative reasons (in your own words) why this expression would be physically reasonable.

2. In the lab is not possible to directly measure the electric field of a light wave. In your own words, explain why.

3. Given the answers to 1 and 2, how do we can get a detect the amount of energy that is carried by an electromagnetic wave?

4. In your homework you will see an expression for the intensity of a electromagnetic wave in terms of the complex amplitude **E** and **H.** Why would this be useful?

Bonus: At a fixed point in time/space, can the Poynting Vector be zero? Justify your answer

PHYS 408 Group Activities for Jan 11 2011

Please complete these exercises without opening the textbook. If you have questions talk with your group mates or raise your hand and Ellen or David will come to help

1. The flow of electromagnetic energy is given by the Poynting Vector ($\vec{\mathcal{S}} = \vec{\mathcal{E}} \times \vec{\mathcal{H}}$) Give at least two qualitative reasons (in your own words) why this expression would be physically reasonable

   1-Units are W/cm^2
   2-E&M waves are transverse waves so direction of propagation and energy flow should be perpendicular to **E** & **H**
   3- $\nabla \cdot \vec{\mathcal{S}} = 0$ (no sources, so no energy creation

2. In the lab is not possible to directly measure the electric field of a light wave. In your own words, explain why.

   They oscillate at approx 300 THz..too fast for any detectors to resolve

3. Given the answers to 1 and 2, how do we can get a detect the amount of energy that is carried by an electromagnetic wave?

   We must measured the time averaged Poynting vector, ie the intensity

4. In your homework you will see an expression for the intensity of a electromagnetic wave in terms of the complex amplitude **E** and **H**. Why would this be useful?

$$I = < |\vec{S}| > = \frac{1}{2} |Re(\vec{E} \times \vec{H}^*)|$$

   Can calculate a measurable quantity (time averaged intensity) directly from the complex amplitude. There is no need to calculate the real electric field from the complex amplitude, then the Poynting vector, then take the time average intensity

Bonus: At a fixed point in time/space, can the Poynting Vector be zero? Justify your answer

Yes, this occurs when the E and H fields are zero,

PHYS 408 Group Activities for Jan 11 2011

Please complete these exercises without opening the textbook. If you have questions talk with your group mates or raise your hand and Ellen or David will come to help

5. What is the simplest solution to the Helmholtz Wave eqn?

$$\nabla^2 \vec{E} + \frac{\omega^2}{c^2} \vec{E} = 0$$

Hint: What is the simplest vector field for $\vec{E}$ *? Does it need to have components along all dimensions?*

Hint: What is the simplest spatial dependence of $\vec{E}$ *(remember it must satisfy all of Maxwell's Eqns)?*

---

6. Your classmate Billy-Bob cannot visualize this simplest solution to the Helmholtz wave equation. Using words and pictures find the best ways to describe this wave. *Hint: the concept of wavefronts will be very helpful.*

PHYS 408 Group Activities for Jan 11 2011

Please complete these exercises without opening the textbook. If you have questions talk with your group mates or raise your hand and Ellen or David will come to help

5. What is the simplest solution to the Helmholtz Wave eqn?

$$\nabla^2 \vec{E} + \frac{\omega^2}{c^2}\vec{E} = 0$$

Hint: What is the simplest vector field for $\vec{E}$ *? Does it need to have components along all dimensions?*

Hint: What is the simplest spatial dependence of $\vec{E}$ *(remember it must satisfy all of Maxwell's Eqns)?*

One example is $\vec{E} = \hat{x}E_o e^{ikz}$ which the real field is $\vec{\mathcal{E}} = \hat{x}E_o cos(kz - \omega t)$

note that the vector field must point in a direction that doesn't have any spatial dependence, otherwise its divergence is not zero and Maxwell's equations aren't satisfied. NOTE that $\vec{E}$ doesn't have any time dependence!!!

---

6. Your classmate Billy-Bob cannot visualize this simplest solution to the Helmholtz wave equation. Using words and pictures find the best way(s) to describe this wave.
Hint: the concept of wavefronts will be very helpful.

See old lecture notes.

7. from my answer to 5, calculate the complex amplitude of the magnetic field.

use one of maxwell's eqns. $\nabla \times \vec{E} = i\omega\mu_o \vec{H}$