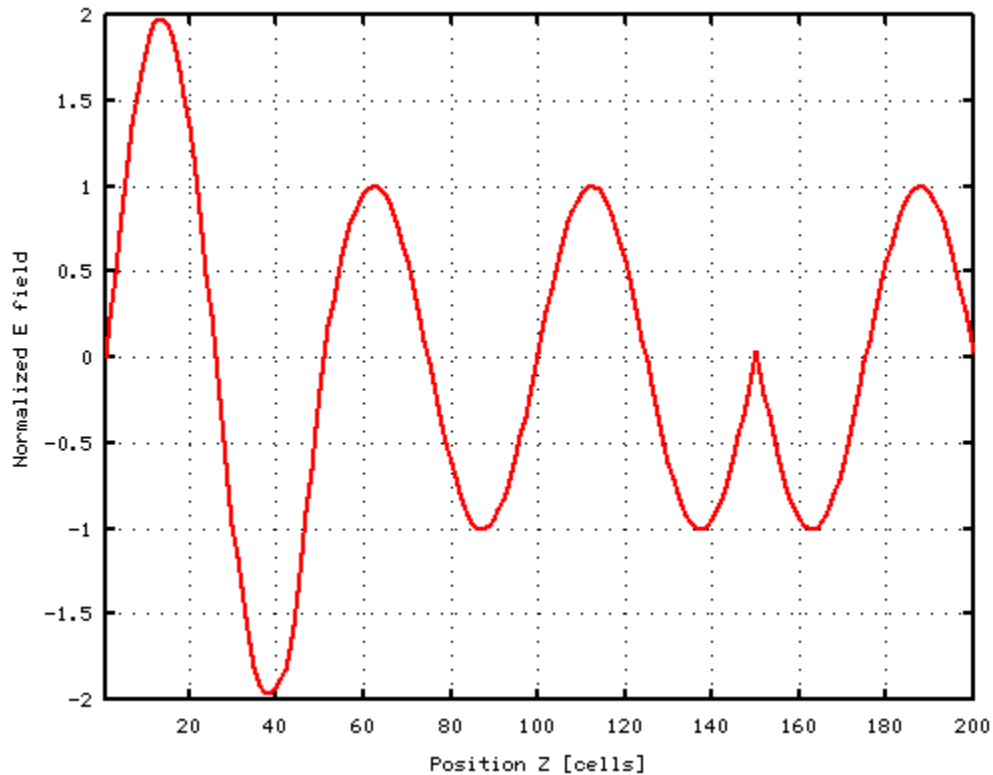


## ECE5430/6430 - Homework 8 Answer Key

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### Problem 1:

Plot of Efield (frequency may vary, and a raised sinusoid can be used instead, but wave on left must be of different amplitude, and wave on right must be absorbed).



*Grading key (points deducted):*

Non-sinusoidal: -2

Problem space != 200 cells: -2

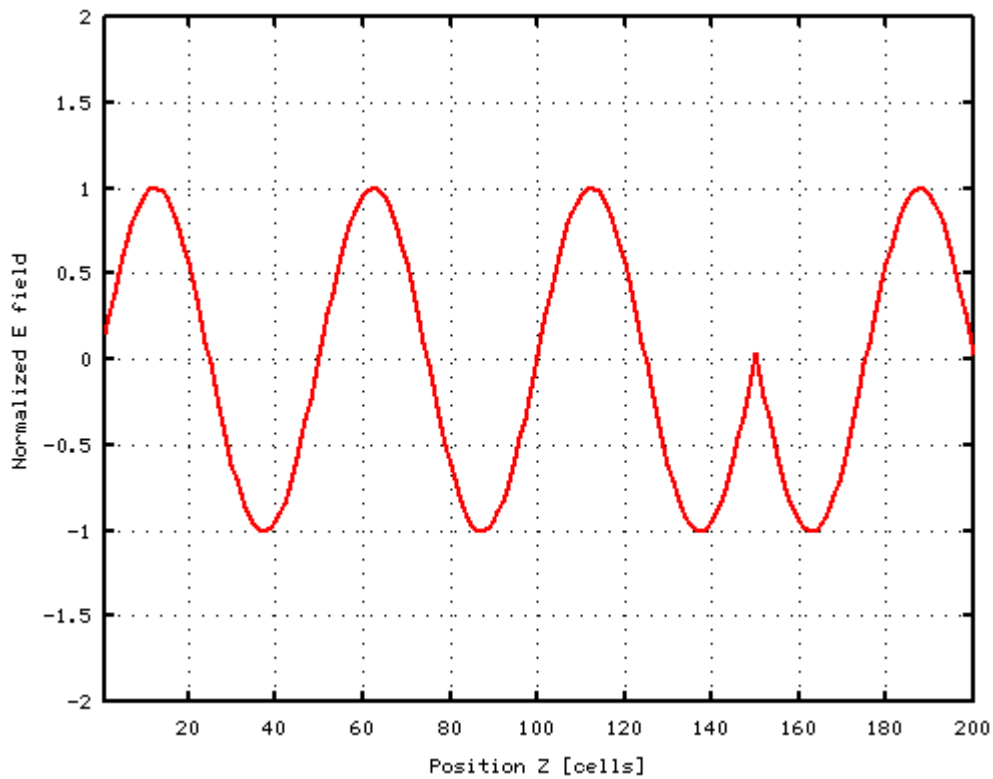
Result not at 400 iterations: -2

Source not at z=150, or H field instead of Efield = -2

Boundary condition incorrect or wrong side: -2

## Problem 2:

**Part 1:** Plot of Efield (frequency may vary, and a raised sinusoid can be used instead, but wave must be absorbed on left and right).



*Grading key (points deducted):*

Non-sinusoidal: -2

Problem space != 200 cells: -2

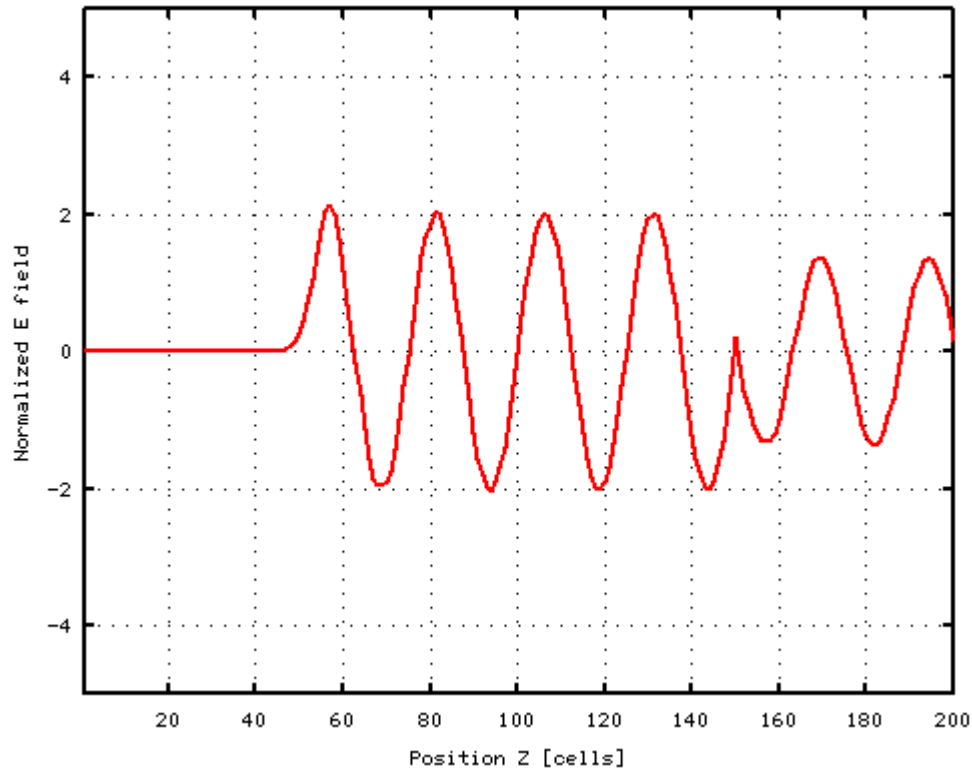
Result not at 400 iterations: -2

Source not at z=150, or H field instead of Efield = -2

Boundary conditions incorrect (i.e. reflected wave): -2

## Part 2:

Plot of Efield. Frequency may vary, and a raised sinusoid can be used instead, but wave must be absorbed on left and right. Wave inside dielectric must have larger amplitude, and higher frequency than before. It will propagate at a shorter wavelength inside the dielectric medium, and will not reach the left boundary of the model.



*Grading key (points deducted for ECE6340, multiply by 1.5 for ECE5340):*

- Non-sinusoidal: -2
- Problem space != 200 cells: -2
- Result not at 400 iterations: -2
- Source not at z=150, or H field instead of Efield = -2
- Boundary conditions incorrect: -2

**Part 3:** See description on Part 1, but also: the simple boundary conditions **do not work**, there are reflections at the edges.

*Grading key:*

- +5 points extra credit if answer mentions the boundary conditions not working.
- No points deducted if question not answered.

### Problem 3:

#### Part 1:

```
e0 = 8.8541e-12;  
u0 = 4*pi*1e-7;  
freq = 1e9;  
c = 1/sqrt(e0*5*u0); % speed of light inside dielectric (worst case)  
lambda = c/freq;  
dz = lambda/20; % Using 20 points instead of ten here, but anything > 10 is good  
dt = dz/(2*c);
```

Which results on:

$$dz = 0.67 \text{ cm}$$

$$dt = 2.5e-11 \text{ s}$$

*Grading key (points deducted for ECE6340, multiply by 2 for ECE5340):*

Wavelength (lambda) calculated in space instead of in dielectric: -2

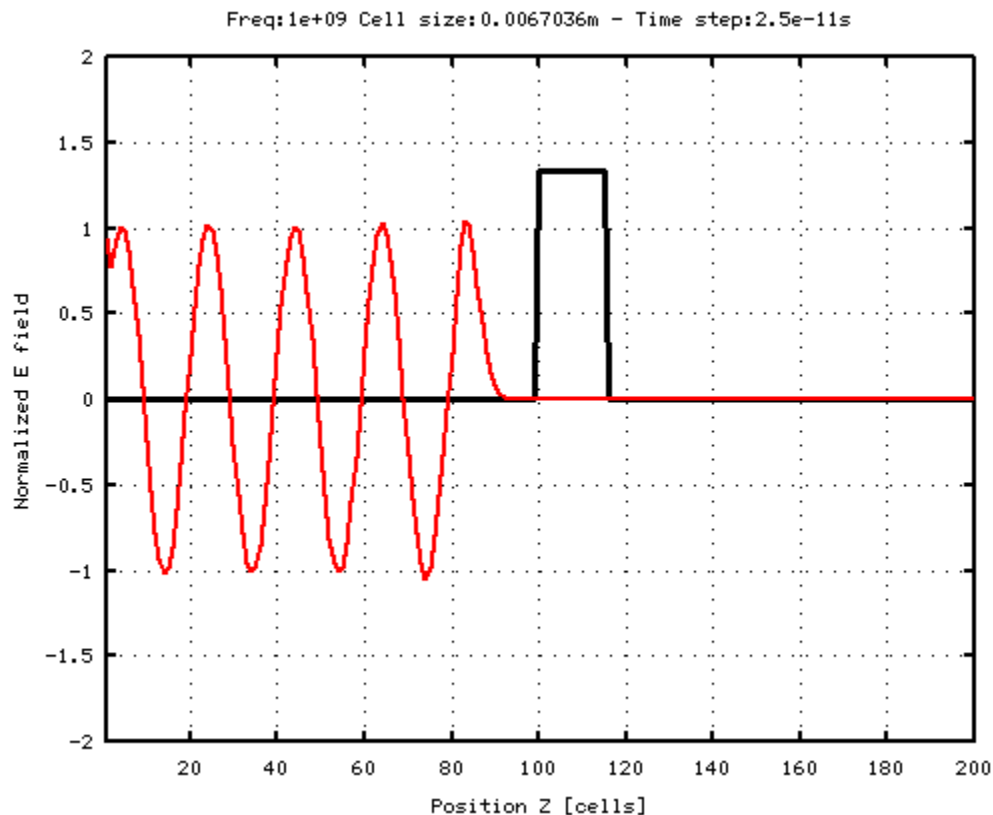
dz calculated using a different expression, or using less than 10 points/wavelength: -2

dt calculated using a different expression: -2

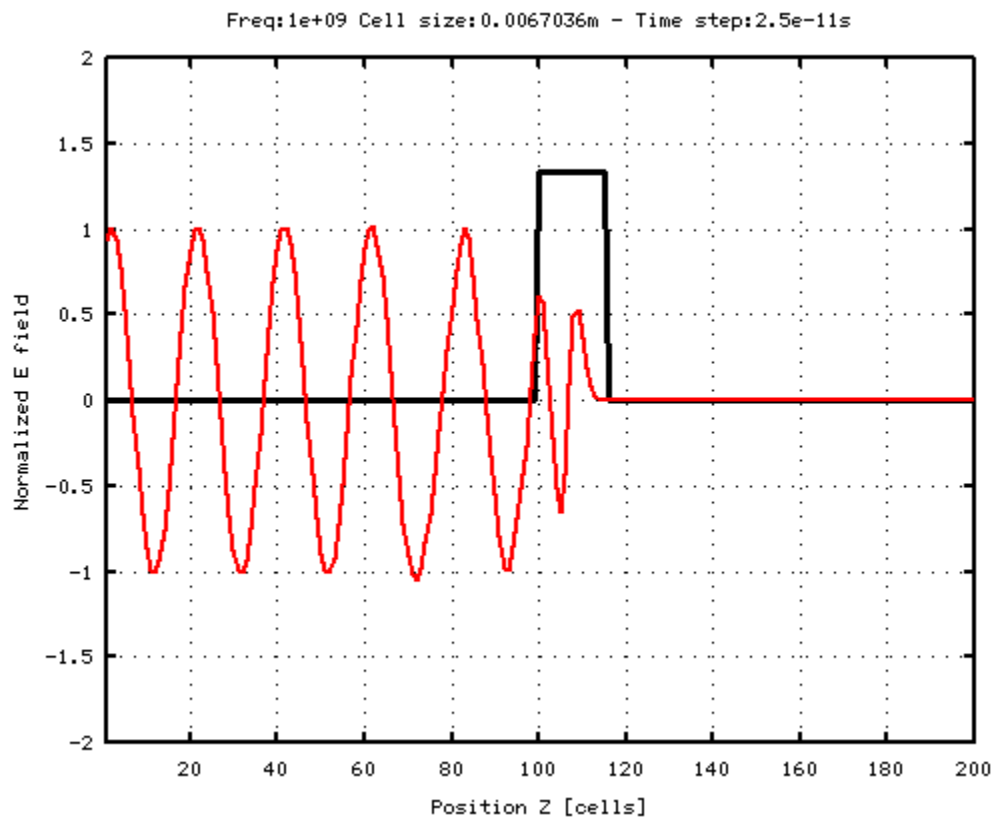
dz or dt results have no units or differ in more than 5 times from values above: -2

Frequency not 1GHz = -2

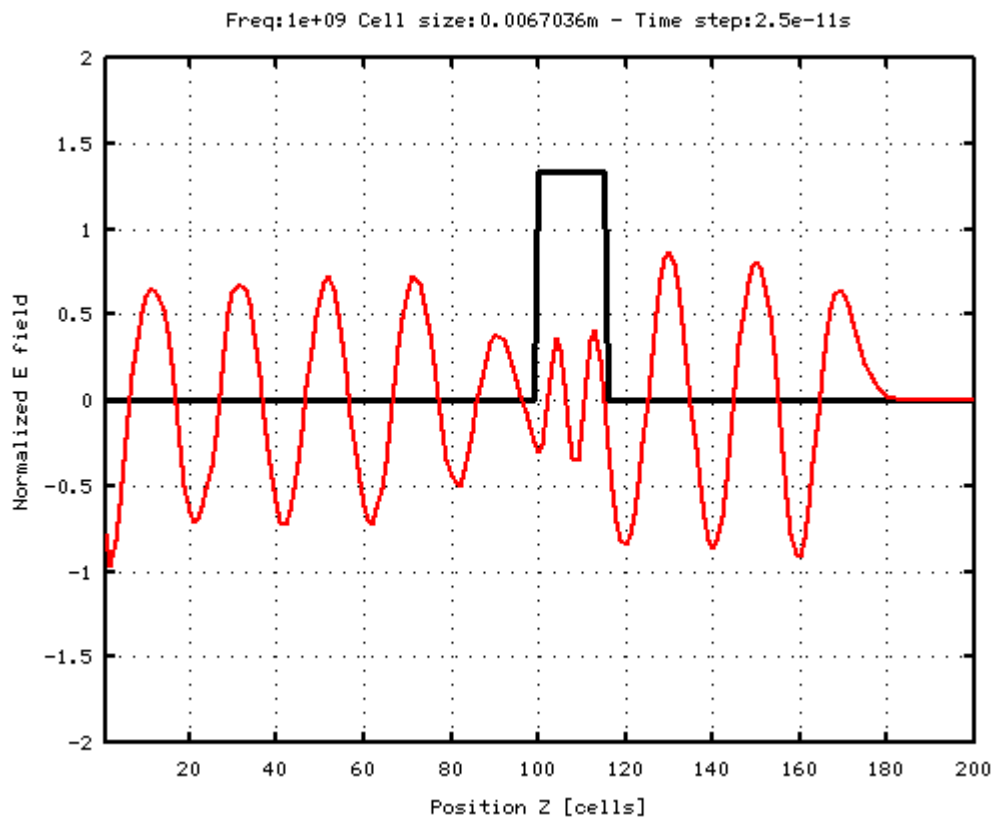
#### Part 2:



Plot 1



Plot 2



Plot 3

*Grading key (points deducted for ECE6340, multiply by 1.5 for ECE5340):*

Slab not approximately 10cm (check number of cells times dz): -3

Epsilon\_r not = 5 on slab: -3

Slab not marked on plots: -5

Plot wrong (no labels, etc) or missing : -3 each plot

#### **Problem 4:**

At 10GHz, and 20 points per wavelength, the cell size is 0.067 cm, and a 10 cm slab is 149 cells wide. (if 10 point per wavelength are used, the cell size is 0.134 cm, and a 10 cm slab is 75 cells wide).

#### **Part 1:** 1<sup>st</sup> interface (coefficients from plots)

$$\text{Transmission coefficient (tau)} = E_t/E_i = 0.6/1 = \mathbf{0.6}$$

$$\text{Reflection coefficient (gamma)} = E_r/E_i = -0.4/1 = \mathbf{-0.4}$$

Verification (optional):

$$\text{Eta1} = \sqrt{u_0/\epsilon_0} = 377$$

$$\text{Eta2} = \sqrt{u_0/(\epsilon_0 * 5)} = 168$$

$$\text{tau} = (2 * \text{Eta2}) / (\text{Eta2} + \text{Eta1}) = 0.61$$

$$\text{gamma} = (\text{Eta2} - \text{Eta1}) / (\text{Eta2} + \text{Eta1}) = -0.38$$

*Grading key (points deducted, max = 10)*

Error > 20% on transmission coefficient: -5

Error > 20% on reflection coefficient: -5

Slab size calculation wrong: -5

Points are not deducted by result's sign (i.e. both -0.4 and 0.4 considered correct for gamma).

#### **Part 1:** 2<sup>nd</sup> interface (coefficients from plots)

$$\text{Transmission coefficient} = E_t/E_i = 0.75/0.6 = \mathbf{1.25}$$

$$\text{Reflection coefficient} = E_r/E_i = 0.25/0.6 = \mathbf{0.42}$$

Verification (optional):

$$\text{Eta1} = \sqrt{u_0/(\epsilon_0 * 5)} = 168$$

$$\text{Eta2} = \sqrt{u_0/\epsilon_0} = 377$$

$$\text{tau} = (2 * \text{Eta2}) / (\text{Eta2} + \text{Eta1}) = 1.38$$

$$\text{gamma} = (\text{Eta2} - \text{Eta1}) / (\text{Eta2} + \text{Eta1}) = 0.38$$

*Grading key (points deducted, max = 10)*

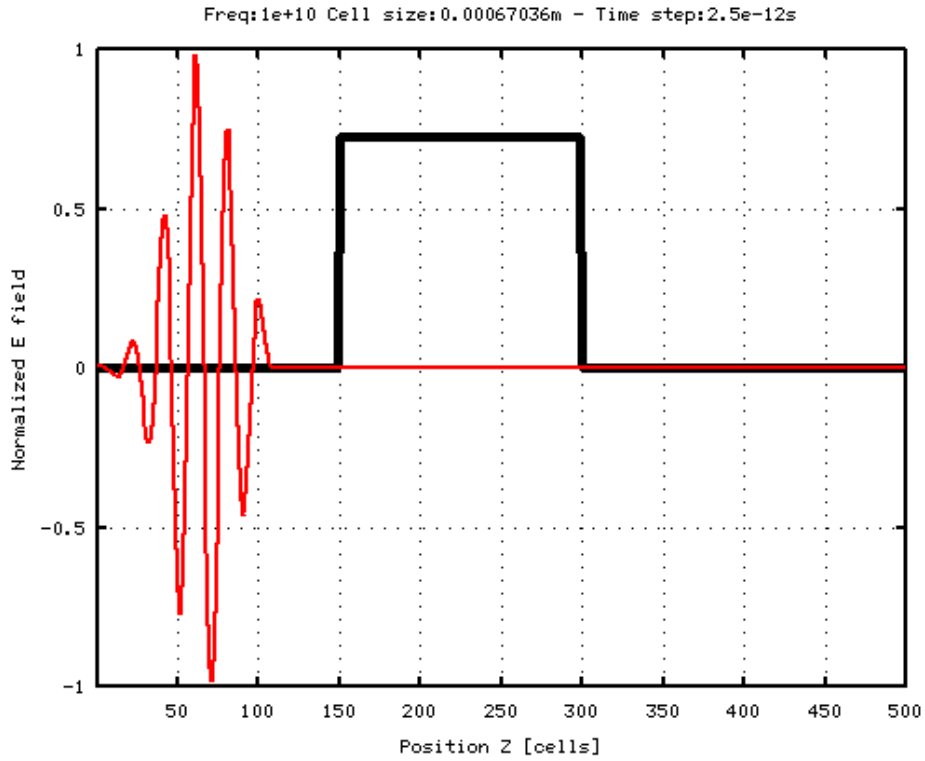
Error > 20% on transmission coefficient: -5

Error > 20% on reflection coefficient: -5

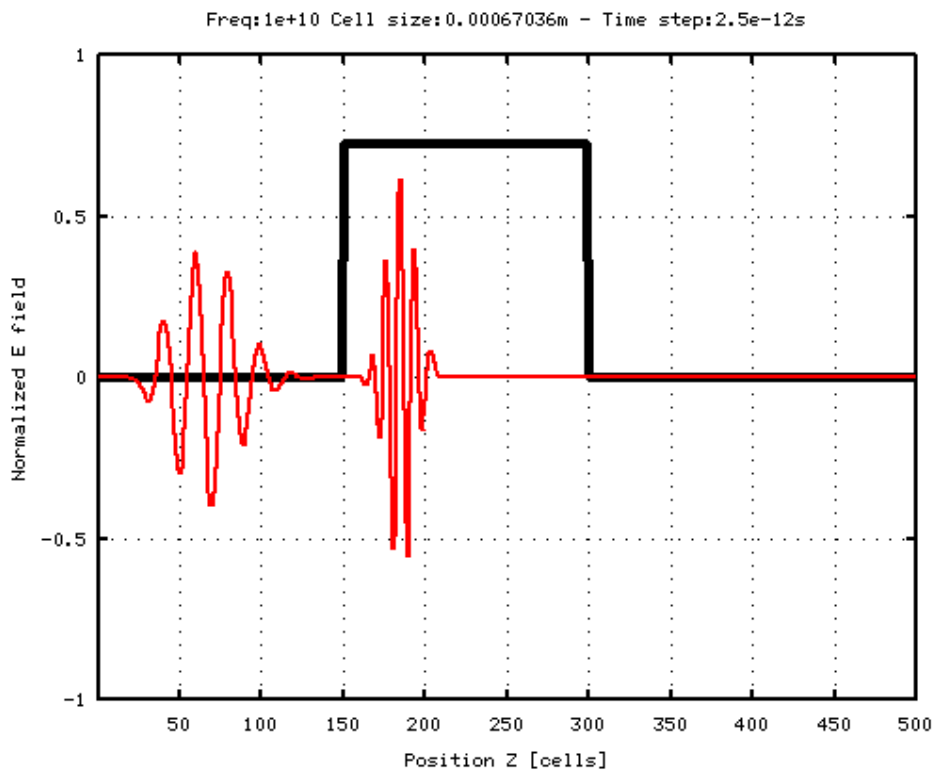
Points are not deducted by sign of result.

Slab size calculation wrong: -5

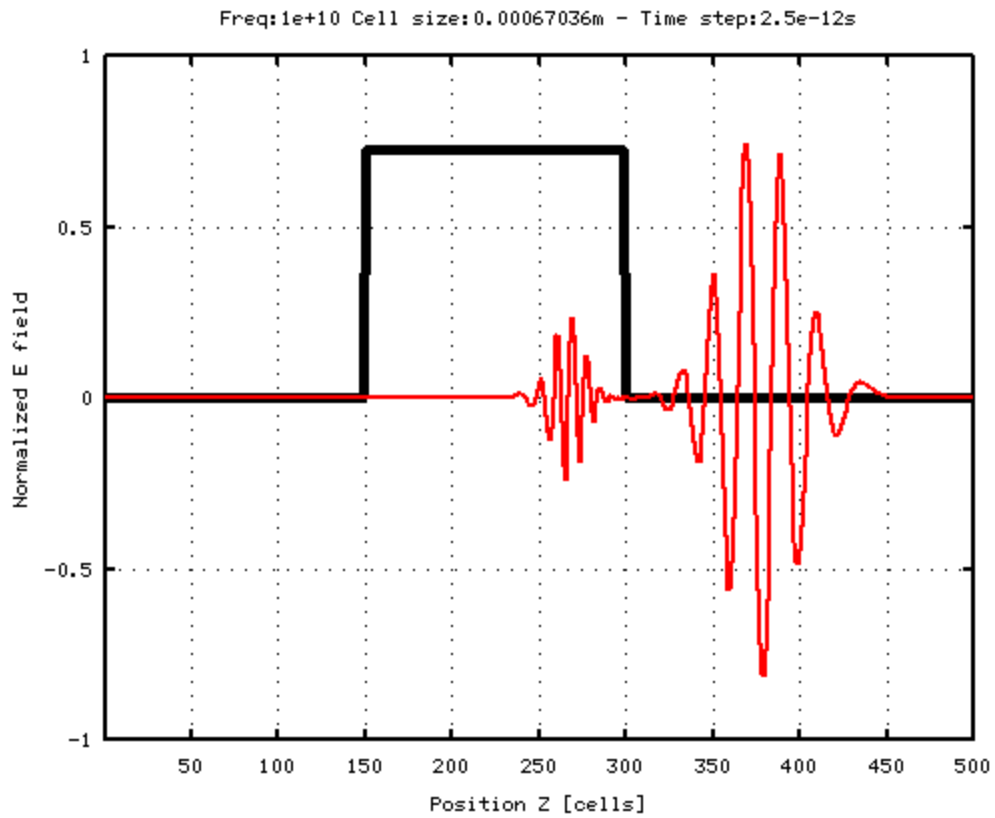
Part 3:



Pulse before impinging on slab - normalized amplitude: 1



Pulse transmitted and reflected at 1<sup>st</sup> interface. Note that reflected pulse is inverted.  
Transmitted pulse amplitude: ~0.6  
Reflected pulse amplitude: ~0.4



Pulse transmitted and reflected at 2<sup>nd</sup> interface.  
Transmitted pulse amplitude:  $\sim 0.75$   
Reflected pulse amplitude:  $\sim 0.25$

*Grading key (points deducted)*

At grader's discretion, up to 3.3 point per plot. Proportions between amplitudes must be correct for plot to earn full points.