Homework #7
Due 18 April

Listen my children and you shall hear
Of the midnight ride of Paul Revere,
On the **eighteenth of April**, in Seventy-five;
Hardly a man is now alive
Who remembers that famous day and year.

He said to his friend, "If the British march
By land or sea from the town to-night,
Hang a lantern aloft in the belfry arch
Of the North Church tower as a signal light,—
One if by land, and two if by sea;
And I on the opposite shore will be,
Ready to ride and spread the alarm
Through every Middlesex village and farm,
For the country folk to be up and to arm."

Then he said "Good-night!" and with muffled oar
Silently rowed to the Charlestown shore,
Just as the moon rose over the bay,
Where swinging wide at her moorings lay
The Somerset, British man-of-war;
A phantom ship, with each mast and spar
Across the moon like a prison bar,
And a huge black hulk, that was magnified
By its own reflection in the tide.

Meanwhile, his friend through alley and street
Wanders and watches, with eager ears,
Till in the silence around him he hears
The muster of men at the barrack door,
The sound of arms, and the tramp of feet,
And the measured tread of the grenadiers,
Marching down to their boats on the shore.

Then he climbed the tower of the Old North Church,
By the wooden stairs, with stealthy tread,
To the belfry chamber overhead,
And startled the pigeons from their perch
On the sombre rafters, that round him made
Masses and moving shapes of shade,—
By the trembling ladder, steep and tall,
To the highest window in the wall,
Where he paused to listen and look down
A moment on the roofs of the town
And the moonlight flowing over all.

Beneath, in the churchyard, lay the dead,
In their night encampment on the hill,
Wrapped in silence so deep and still
That he could hear, like a sentinel's tread,
The watchful night-wind, as it went
Creeping along from tent to tent,
And seeming to whisper, "All is well!"
A moment only he feels the spell
Of the place and the hour, and the secret dread
Of the lonely belfry and the dead;
For suddenly all his thoughts are bent
On a shadowy something far away,
Where the river widens to meet the bay,—
A line of black that bends and floats
On the rising tide like a bridge of boats.

Meanwhile, impatient to mount and ride,
Booted and spurred, with a heavy stride
On the opposite shore walked Paul Revere.
Now he patted his horse's side,
Now he gazed at the landscape far and near,
Then, impetuous, stamped the earth,
And turned and tightened his saddle girth;
But mostly he watched with eager search
The belfry tower of the Old North Church,
As it rose above the graves on the hill,
Lonely and spectral and sombre and still.
And lo! as he looks, on the belfry's height
A glimmer, and then a gleam of light!
He springs to the saddle, the bridle he turns,
But lingers and gazes, till full on his sight
A second lamp in the belfry burns.

A hurry of hoofs in a village street,
A shape in the moonlight, a bulk in the dark,
And beneath, from the pebbles, in passing, a spark
Struck out by a steed flying fearless and fleet;
That was all! And yet, through the gloom and the light,
The fate of a nation was riding that night;
And the spark struck out by that steed, in his flight,
Kindled the land into flame with its heat.

He has left the village and mounted the steep,
And beneath him, tranquil and broad and deep,
Is the Mystic, meeting the ocean tides;
And under the alders that skirt its edge,
Now soft on the sand, now loud on the ledge,
Is heard the tramp of his steed as he rides.

It was twelve by the village clock
When he crossed the bridge into Medford town.
He heard the crowing of the cock,
And the barking of the farmer's dog,
And felt the damp of the river fog,
That rises after the sun goes down.

Homework #7
Due 18 April

It was one by the village clock,
When he galloped into Lexington.
He saw the gilded weathercock
Swim in the moonlight as he passed,
And the meeting-house windows, black and bare,
Gaze at him with a spectral glare,
As if they already stood aghast
At the bloody work they would look upon.

It was two by the village clock,
When he came to the bridge in Concord town.
He heard the bleating of the flock,
And the twitter of birds among the trees,
And felt the breath of the morning breeze
Blowing over the meadow brown.
And one was safe and asleep in his bed
Who at the bridge would be first to fall,
Who that day would be lying dead,
Pierced by a British musket ball.

You know the rest. In the books you have read
How the British Regulars fired and fled,—
How the farmers gave them ball for ball,
From behind each fence and farmyard wall,
Chasing the redcoats down the lane,
Then crossing the fields to emerge again
Under the trees at the turn of the road,
And only pausing to fire and load.

So through the night rode Paul Revere;
And so through the night went his cry of alarm
To every Middlesex village and farm,—
A cry of defiance, and not of fear,
A voice in the darkness, a knock at the door,
And a word that shall echo for evermore!
For, borne on the night-wind of the Past,
Through all our history, to the last,
In the hour of darkness and peril and need,
The people will waken and listen to hear
The hurrying hoof-beats of that steed,
And the midnight message of Paul Revere.

by Henry Wadsworth Longfellow

Would history have been different if Paul Revere had a telegraph or mobile phone?

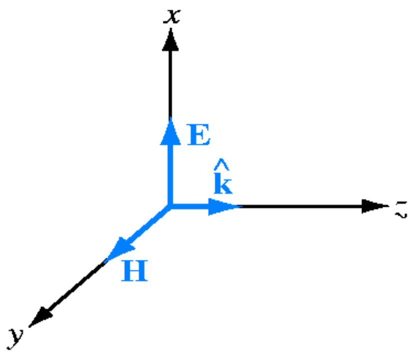
1. Plane Waves in Lossless Media

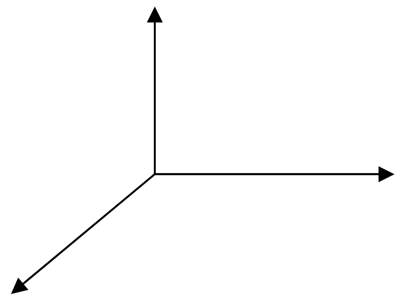
A uniform plane wave is propagating in the z-direction in the air of an unknown planet at a frequency of 5.8GHz (which is a new wireless band here on earth). Using information from an online source, the average power in a WiFi signal is typically around 0.04 milliWatts per square centimeter. For the purposes of this problem, assume that the wave is randomly polarized, so that half of its energy is in one polarization and half in the other. Thus, for all of the following questions, you need to be sure that you indicate fields with both polarizations. It is easiest to do this separately and not write them in the same expression, but that is also an option. The relative permittivity of the air on this planet is $\varepsilon_r = 1.5$ and the air is non-magnetic. Find:

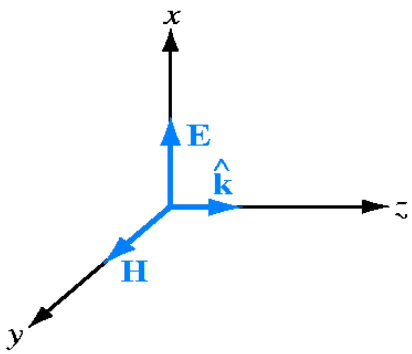
a) The magnetic field phasor $\tilde{\vec{H}}(z)$
b) The electric field phasor, $\tilde{\vec{E}}(z)$
c) The angular frequency ω period of the wave, T.
d) The phase velocity, u_p
e) The wavelength in the material, λ, and the propagation constant of the wave, β.
f) The intrinsic impedance of the air on this planet η.

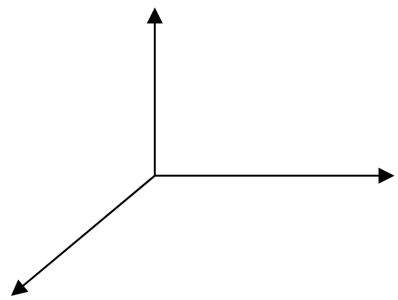
Draw the diagram analogous to figure 7-4 of Ulaby showing the direction of the magnetic field phasor $\tilde{\vec{H}}(z)$, the electric field phasor $\tilde{\vec{E}}(z)$ and the direction of wave propagation for both polarizaitons. Figure 7-4 is copied below as a reference and a set of coordinate axes are also provided. Please thoroughly label your diagram.

Homework #7
Due 18 April









We can now use the information obtained for the fields in the time domain. Find:

g) The electric field in time domain form, $\vec{E}(z,t)$

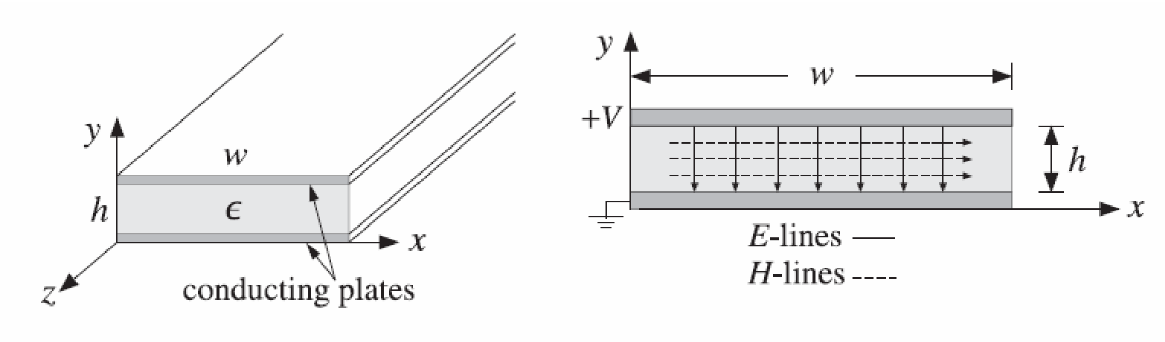
h) The magnetic field in time domain form, $\vec{H}(z,t)$

Let us now assume that the uniform electromagnetic wave is propagating in the insulating region between two conducting plates that forma parallel plate transmission line. (See figure below) We can use the information we have on the fields to find the voltage and current on the line. Note that one of the polarizations will be shorted out by the plates of the transmission line but the other will propagate. Find:

i) The phasor voltage on the top plate $\hat{V}(z)$ by integrating the electric field phasor from the bottom plate to the top plate. Assume that the bottom plate is grounded (one of them has to be).

j) The phasor current in either the top or bottom plate $\hat{I}(z)$ by applying Ampere's Law to a closed loop surrounding one of the plates. Note that the magnetic field is assumed to be zero in the regions outside of the transmission line (no fringing field assumption).

k) The ratio of the voltage to the current. Compare your answer to the characteristic impedance of this transmission line. Indicate where you obtained the expression for the characteristic impedance.



Finally, using Maple, Matlab or some similar tool, plot the magnitudes of electric and magnetic fields of the waves as a function of position at three times, $t = 0$, $t = T/3$, $t = 2T/3$.

2. **Power Absorption in a Lossy Material**

A uniform plane wave ($f = 2.45GHz$) is propagating in a piece of turkey in a microwave oven. The electric field intensity of the wave is unknown at this point (you will be asked to determine it), but assume it is given by the constant E_o. We wish to investigate the heating of the turkey by the wave and the resulting electric and magnetic fields. A reference containing information on the electrical properties of a wide variety of materials: http://www.rfcafe.com/references/electrical/dielectric_constants_strengths.htm Note that the data provided gives the loss tangent, not the imaginary part of the permittivity. For the heating of turkey, you can find typical dielectric properties in the paper posted in the supplementary materials page under *Simulation of Microwave Heating.* Assume that 300 Watts are deposited in a cube of turkey 10 cm by 10 cm by 10 cm (we are assuming a cubical turkey).

Assume that the direction of wave propagation is +z. Determine the following:

a) The loss tangent for turkey.
b) The basic wave parameters ω, α, β, λ, and η_c.
c) The electric field phasor $\tilde{\vec{E}}(z)$ and the magnetic field phasor $\tilde{\vec{H}}(z)$ in terms of E_o.
d) The phase velocity, u_p.
e) From the average power deposited in a 10 centimeter by 10 centimeter by 10 centimeter cube of turkey between using the integral of $\frac{1}{2}\mathrm{Re}\,\vec{J}(z)\cdot\vec{E}^*(z)$ as in lecture 21, determine the electric field intensity E_o.
f) The average power density (Poynting Vector) at $z = 0m$, that is, at the front surface of the cube of turkey.

Compare your answers to parts e) and f).