Physics 3034 – Spring 2026 – Rev B1

Submit on paper or upload by February 16.

Homework 03

SPN 3–01 Drude model of conduction.

The density of Lithium metal is 530 kg/m^3 and its atomic weight is 7. The mass of a proton is 1.67×10^{-27} kg and you can assume a neutron has the same mass.

[**a**] Using the information given above, calculate n (the number of Li atoms per m^3) and a (the distance between adjacent Li atoms). You may assume a simple cubic lattice to make your calculations easier.

[**b**] Calculate the thermal kinetic energy and average speed of a free electron at room temperature. You need a formula from statistical mechanics to do this. That formula is $1/2\ mv^2 = 3/2\ k_B T$. (k_B is Boltzmann's constant, T is temperature in Kelvin).

[**c**] Based on your results for a and b, calculate the time (τ) between electron collisions with adjacent Lithium atoms. Assume every electron hits every atom it comes across.

[**d**] You now know enough to calculate the electrical conductivity (σ) of Lithium based on the Drude model. You need to assume that every lithium atom contributes one free electron to the metal. Calculate σ.

[**e**] Repeat the calculations for Magnesium, which contributes two free electrons per atom.

[**f**] Look up the measured values of σ for these two metals. What do you see that is consistent with the Drude model? To the extent that your calculations differ from measurements, speculate on what might be different? (There are many good answers that you can give to this, just think about it.)

SPN 3–02 – Fun with EM units.

Based on the definitions of each, write an expression for the ratio of conduction current density to Maxwell current density. Show that this ratio $J_{maxwell}/J_{conduction}$ is dimensionless.

SPN 3–03 – More fun with EM units.

You probably know that $c = \sqrt{\frac{1}{\epsilon_0 \mu_0}}$. Plug in the values and units for ϵ_0 and μ_0 to show this comes out correctly.

SPN 3–04 – Maxwell's equations in linear media.

Here are the "constitutive relations" for a linear dielectric/paramagnetic medium.

$$\vec{D} = \epsilon_r \epsilon_0 \vec{E} \tag{1}$$

$$\vec{B} = \mu_r \mu_0 \vec{H} \tag{2}$$

[**a**] Write down all four Maxwell equations in vacuum in differential form in a linear dielectric and para/diamagnetic medium in terms of $\vec{B}$ and $\vec{E}$.(Feel free to just copy these from Table C.2 in Appendix C of the book. I may well ask you to memorize these for the first exam.

[**b**] Derive the integral form from the differential form for all 4 equations. (In class I derived the differential form from the integral form). Your derivation should show how you explicitly integrate both sides with respect to length, area or volume and should also include stating when you use Stoke's theorem or the divergence theorem.

SPN 3–05 – Electromagnetic Wave Equation in linear media.

Begin with the following two equations.

$$\nabla \times \vec{E} = -d\vec{B}/dt \tag{3}$$

$$\nabla \times \vec{H} = \epsilon d\vec{E}/dt \tag{4}$$

[**a**] Take the cross product of both sides of equation 3 and use the vector identity for the curl of a curl to arrive at a wave equation for $\vec{B}$. Justify your steps.

[**b**] Do the same for $\vec{E}$. Justify your steps.

[**c**] If ϵ_r =3 and $\mu_r = 1.1$, calculate the speed of light in this medium.

SPN 3–06 – Poynting Vector.

Do Griffiths 8.2.

SPN 3–07 – Poynting Vector.

Griffiths 8.1 has two parts. Just do the first part (Poynting vector of currents flowing along an inner cylinder and returning along an outer cylinder).