Name _____ Net ID_____

TA Name_____ Discussion Section_____

PHYS 212 James Scholar Assignment #5

The problems are to be done on paper, **showing all work**. Again, *the presentation should be neat, legible, and easy to follow.*

{Remember to include your name, netID, and Discussion section and ideally TA name on the top of the page! Please turn in your assignment into the Grading Box labeled "Physics 212 James Scholars", located on the 2nd floor, in the interpass between Loomis and MRL (Materials Research Lab). The interpass is down the hall about 10 meters east of Room 262 Loomis, where half of you have your Lab.}

This topic is all about creating materials ('metamaterials') that have an effectively *negative* index of refraction. One consequence is that, in constrast to normal electromagnetic waves which propagate according to the right-hand rule (i.e., the wave propagates in the direction given by E X B), in a negative-index material, you need to use a *left*-hand rule instead (for this reason, these are sometimes called 'left-handed' materials). There are many interesting consequences of this, and many amazing applications, such as superlenses and 'invisibility cloaks'. Hopefully you will find that the things you have learned in Physics 212 are quite relevant for this fascinating topic (they discuss index of refraction, energy transfer, resonant systems,lenses, etc.). Enjoy!

NOTE: We advise reading these in the following order...

- D. R. Smith, David Smith's website information on metamaterials., (http://people.ee.duke.edu/~drsmith/metamaterials.htm)
- D. R. Smith, David Smith's website information on negative-index materials (play around with the animations) (http://people.ee.duke.edu/~drsmith/negative_index_about.htm)
- J. B. Pendry and D. R. Smith, 'The Quest for the Superlens', Scientific American, pp 60-68 (July 2006) http://courses.physics.illinois.edu/phys212/sp2013/JamesScholars/05/SuperlensShort.pdf
- U. Leonhardt, 'Invisibility Cup', Nature Photonics 1, pp. 207-208 (Apr. 2007)
- http://courses.physics.illinois.edu/phys212/sp2013/JamesScholars/05/CloakingLeonhardt.pdf

- www.photonics.com 'Cloak of Partial Invisibility Created', https://www.photonics.com/wa27111

- D. Schurig, et al., 'Metamaterial Electromagnetic Cloak at Microwave Frequencies',Science 314, pp. 977-980 (Nov. 2006).[[You can just look at the Figures (and captions), though of course you can read the entire article too if you want!]]

- www.photonics.com ''Optical cloaking' design created for invisibility', https://www.photonics.com/Articles/rsquoOptical_Cloakingrsquo_Design_Created_for/a29193

If you are still curious, you may find the following article of interest, though it's a bit more advanced:

- D. Felbacq, 'Envisioning Invisibility: Recent advances in cloaking', Optics and Photonics News, pp 32-37 (June 2007).[[The last four sections are quite readable/informative.]]

1. **Materials demonstrating a negative index of refraction have never been found in nature.**
   - true
   - false

2. **Negative-index materials can be constructed using specially designed microscopic structures; however, it is necessary that the size of the individual elements be much less than the wavelength of electromagnetic radiation they are designed for.**
   - true
   - false

3. **Which of the following could best be used to model a split-ring resonator (SRR)?**
   - a coupled inductor-capacitor circuit
   - a quarter waveplate/linear polarizer combination
   - a collection of atomic electric and magnetic dipoles

4. **What object was cloaked in the ground-breaking experiments by Schurig and Smith?**

- a copper tube
- an aluminum star
- a tiny platinum model of a Romulan spaceship

5. **What was the (free-space) wavelength at which Schurig and Smith demonstrated electromagnetic 'cloaking'? (Note: You may have to calculate this from other information.)**

- 633 nm
- 10 mm
- 35 mm
- 0.88 m

6. **Which of the following is *not* a major limitation of realization cloaking of visible objects?**

- Most designs only work for a single wavelength.
- It is difficult to make the metamaterial micro-circuit elements small enough.
- There are too many different polarizations to account for with visible light.
- The increased resistance of the metals used to make the metamaterial tends to damp out the resonance on which metamaterials rely.

7. **In spring 2007 a group at Purdue *experimentally* demonstrated 'optical cloaking' at visible wavelengths.**

- true
- false

Now please complete the following survey regarding your James Scholar experience this past semester.

8. **I felt that the additional James Scholar assignments were**
   - ○ very interesting.
   - ○ moderately interesting.
   - ○ rather uninteresting.
   - ○ a complete waste of time.

9. **I felt that the level of difficulty of the assignments was**
   - ○ too hard.
   - ○ just right.
   - ○ too easy.

10. **I would value these sorts of assignments if they were also given in Physics 211, 213 and 214.**
   - ○ very much
   - ○ somewhat
   - ○ not at all

11. **I thought that the total number of assignments given was**
   - ○ too few.
   - ○ just right.
   - ○ too many.

12. **In the future I would encourage other students to sign up for honors credit in this fashion.**
   - ○ true
   - ○ false

13. **Please tell us any other comments you have regarding your experience with this experimental approach to honors credit.**