Physics 3034 – Spring 2025 – Rev B
    First 4 problems are due by February 10.
Last two can be uploaded on the 11th.

Homework 02

For numerical answers, show numbers plugged into the equation before solving with a calculator. Numerical answers should include SI units.

SPN 2–01 The original form of Ampere's law (before Maxwell) is

$$\nabla \times \vec{B} = \mu \vec{J} \tag{1}$$

[a] Take the divergence of this equation and explain (briefly) the problem.
[b] Repeat the previous step including the Maxwell Current density and show that the problem is fixed.

SPN 2–02 – Energy in a magnetic field.
The energy stored in an inductor is $U = \frac{1}{2}LI^2$. This can be used to derive the energy density in a magnetic field.

[a] Beginning with Ampere's law, derive an expression for the magnetic field in a long solenoid of radius s, length ℓ, with total windings N and current I. (You have done this before, but it is worthy review.)
[b] Using the result from part a, and the definition of inductance $\Phi = LI$, derive an expression for the self inductance of this solenoid.
[c] Use the result from parts a and b to derive the energy density in a magnetic field.
[d] A neutron star can have a magnetic field of a Teragauss. How much energy is stored in a cubic centimeter of neutron star magnetic field?
[e] Express the answer to d in kilowatt-hours.

SPN 2–03 – Application of displacement current.
Do Griffiths 7.34.

SPN 2–04 – Application of displacement current.
Do Griffiths 7.40.

    THERE ARE TWO MORE PROBLEMS ON THE NEXT PAGE!!

1 Matrix method tricks you need for the following problems.

As shown on page 406 and figure 9 of Pedrotti, you can use certain Matrix elements to tell you the location of the focus, the location of the image, and the magnification of the image. For thick lenses or complex lens systems, it is no longer the case that the front focal length and the back focal length are the same. However the principle of reversibility still holds.

Matrix element 'A' is zero The distance from the right of the rightmost lens is the back focal length.

Matrix element 'B' is zero The distance from the right of the rightmost lens is the image distance.

Matrix element 'B' is zero When 'B' is zero, the value of 'A' is the magnification.

1.1 Reference Files

```
matrixoptics_hw.py   -- Working code that you will modify to solve the given problem
matrixoptics_hw.py.pdf   -- Same code with nice colors to help you read it.
tugraz_sim.pdf   -- This is the simulation you are going to reproduce.
```

SPN 2–05 Run the python code provided (see Reference files above). It will print out three matrices for a thin lens for three different object/image distances.

[a] Which of the three matrices have object and image distances which are correct, and how do you know?
[b] For the ones that ARE correct, what are the object and image distances AND the magnification?
[c] Since this is a thin lens, you should be able to calculate its focal length with the lens-maker's equation. (Relevant properties are given in the python code.)
[d] Having calculated the focal length, check the answers from part b with the simple 1/f = 1/s + 1/s' formula.

SPN 2–06 Referring to the parameters listed in the "tugraz" file:

[a] Write the "compose_thick" function
[b] Change "main" to include a call to compose_thick and pretty_print the matrix.
[c] You were told the object distance (it"s 6 cm). You can figure out the image distance by guessing and running the code over and over until element B is zero. Or you could be more clever in a couple of ways. Explain what you did.
[d] So what is the back focal length and the image distance for this setup.
[e] Submit your modified code and a screen capture of its output.