PART I: MULTIPLE CHOICE

Each multiple choice question has one best answer -- circle the letter of the best answer. **Partial credit will be given on the multiple choice questions.** If you circle two answers, one of which is correct, you will receive half credit for the question. No credit will be given for more than two answers, even if one of them is correct. (4 points each for full credit)

1. The magnetic field-line pattern around the two bars in the figure shows that

   a) neither bar is a permanent magnet.
   b) both bars must be permanent magnets with like poles adjacent to each other.
   c) either both bars are permanent, or one is permanent and one is a soft iron bar, but in either case the like poles are adjacent.
   d) both must be identical permanently magnetized bars with opposite poles adjacent to each other.
   e) none of these

2. When placed askew in a magnetic field, a current-carrying loop that is free to rotate in any direction will experience a torque until its magnetic moment vector

   a) is at a right angle to the magnetic field vector.
   b) makes a 45° angle with the magnetic field vector.
   c) makes an angle of 270° with the magnetic field vector.
   d) is aligned with the magnetic field vector.

3. The figure shows a horizontal length of copper wire moving across a horizontal magnetic field. There will be

   a) a negative voltage induced across its ends.
   b) a positive voltage induced across its ends.
   c) no voltage induced across its ends.
   d) a time-varying voltage induced across its ends.
   e) none of these

4. The bar magnet is moving at a constant speed toward the coil. The voltage measured across the resistor is

   a) higher at B than A, and increasing.
   b) higher at A than B, and increasing.
   c) zero.
   d) higher at A than B, and decreasing.
   e) higher at B than A, and decreasing.
5. In an R-L ac series circuit,
   a) the instantaneous current and voltage are in phase everywhere.
   b) the instantaneous current leads the voltage across L.
   c) the instantaneous voltage across L leads the current.
   d) the instantaneous voltage across L lags the current by 90°.
   e) none of these

6. When a beam of light traveling in air enters a glass block, it ordinarily undergoes a change in
   a) speed only.
   b) frequency only.
   c) wavelength only.
   d) speed and wavelength.
   e) none of these

7. A convex lens with a very small focal length is placed in contact with a convex lens with a very large focal length. The combined focal length will be
   a) much larger than either.
   b) much smaller than either.
   c) approximately equal to the larger.
   d) approximately equal to the smaller.
   e) none of these

8. Suppose that in lab you were given a bag of lenses that are marked with the following diopter values: +1.0 D, -4.0 D, +10 D, +0.10 D, +95 D, and -0.50 D. If asked to make a microscope with the largest possible magnification, which lenses would you choose?
   a) +0.10 D as objective and +95 D as eyepiece
   b) -4.0 D as objective and -0.50 D as eyepiece
   c) +95 D as objective and +10 D as eyepiece
   d) +10 D as objective and +0.10 D as eyepiece
   e) none of these
PART II: FREE RESPONSE

9. A 8-μF capacitor in series with a 20-kΩ resistor is charged by a 100 V battery. A neon lamp is connected across the capacitor (in parallel with it). A neon lamp has a very high resistance before it “fires”, i.e. turns on. The neon gas has to ionize for the bulb to fire and it won’t do so until a threshold voltage of 70 V is reached. When the voltage across it reaches 70 V, it fires and its resistance drops almost instantaneously to zero, thus behaving like a short across the capacitor in the circuit. This results in periodically discharging the capacitor. This kind of circuit is used to make a flashing light (like the directional signal in your car).
(a) Sketch a graph of the voltage across the capacitor versus time. Label the axes and put appropriate numbers on them. [7 pts]
(b) Determine the frequency at which the light (neon lamp) will flash in the circuit. [10 pts]
10. The force on a current-carrying wire is a maximum of 5.30 N when placed between the pole faces of a magnet. The current flows horizontally (between the pole faces) and the magnetic field is vertical. The wire is observed to “jump” when the current is turned on.

(a) What direction does the wire jump? (towards you, away from you, up, or down?) Justify your answer with a brief explanation. [7 pts]

(b) If the pole faces measure 10.0 cm on a side, estimate the current in the wire if the magnetic field is 0.50 T. [10 pts]
11. A capacitor is placed in parallel across a load to filter out stray high-frequency signals (like voltage spikes and glitches), but to allow ordinary 60 Hz ac to pass through with little loss. Suppose that the load in the figure is a resistance of $R = 300 \, \Omega$ connected to the wall outlet, and that $C = 0.60 \, \mu F$. What percent of the incoming current will pass through C rather than R if
(a) it is 60 Hz? [10 pts]
(b) it is 60 kHz? [7 pts]
Choose either problem 12 or 13.

12. Each student in a physics lab is assigned to find the location where a candle may be placed in order that a concave mirror with radius of curvature $R = 40$ cm will produce an image three times the size of the object. Two students complete the assignment at different times using identical equipment, but when they compare notes later, they discover that their answers for the object distance are not at all the same — the discrepancy is much greater than experimental uncertainties would predict. They figure out that, even though their answers are quite different, they are both correct. Explain their reasoning [5 pts] and justify their conclusion by calculating two possible answers to this problem [12 pts].
13. A 31.0 cm focal length converging lens is 21.0 cm behind a diverging lens. Parallel light rays strike the diverging lens. After passing through the converging lens, the light is again parallel.
(a) Draw a ray diagram of the situation. Try to keep the drawing to scale and indicate the location of all the focal points. [7 pts]
(b) What is the focal length of the diverging lens? [10 pts]