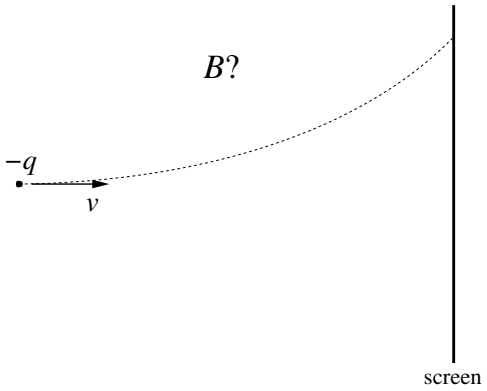
Circle the letter of the single best answer. Each question is worth 1 point

Physical Constants:

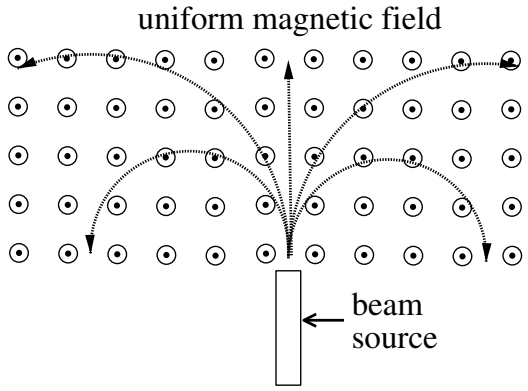
proton charge = $e = 1.60 \times 10^{-19}$ C
proton mass = $m_p = 1.67 \times 10^{-27}$ kg
electron mass = $m_e = 9.11 \times 10^{-31}$ kg
electron charge = $-e = -1.60 \times 10^{-19}$ C
permittivity of free space = $\epsilon_0 = 8.85 \times 10^{-12}$ F/m
permeability of free space = $\mu_0 = 4\pi \times 10^{-7}$ T·m/A
Coulomb constant = $k_e = 9 \times 10^9$ N · m^2/C^2
Faraday constant = 9.65×10^4 C
speed of light = $c = 3 \times 10^8$ m/s

1. An electron moves horizontally toward a screen. The electron moves along the dotted path because of a magnetic force caused by a magnetic field. In what direction does that magnetic field point?



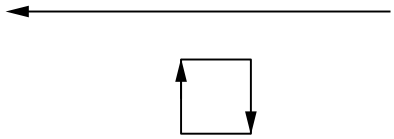
A. Toward the top of this page
B. Toward the bottom of this page
C. Into this page
D. Out of this page

2. A beam consists of an unknown mix of particles. All the particles have the same velocity. The beam directs the particles into a region of uniform magnetic field (pointing out of the page—much like a mass spec). The following figure displays some possible paths for particles. Note the following names: proton (the positively charged nucleus of normal hydrogen), deuteron (the nucleus of an isotope of hydrogen: twice the mass of a proton, but with the same charge), α particle (He nucleus: four times the mass of a proton and twice the charge of a proton), electron (negatively charged particle orbiting the nucleus in Bohr's atom).



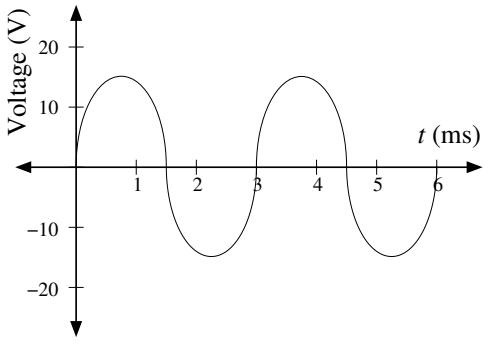
A. The proton, deuteron and α all follow different paths, with the more massive particles having the largest radius path.
B. The proton and deuteron follow the same path.
C. The deuteron and the α follow the same path.
D. The radius of the electron's path is much larger than the radius of the proton's path and curves in the opposite direction.

3. A current is flowing clockwise around a square loop; additionally a current is flowing to the left through a long straight wire that sits above the square. The square loop and the wire sit in the plane of this sheet of paper as shown in the below figure. The current flowing in the square loop constitutes a magnetic dipole (like a little bar magnet with poles perpendicularly above/below the loop). Recall that, like a compass needle, such a dipole 'wants' (i.e., releases energy) if it is aligned with an external magnetic field. Which way does the magnetic field due to the long wire point at the center of the square loop? Will the loop 'want' to flip?

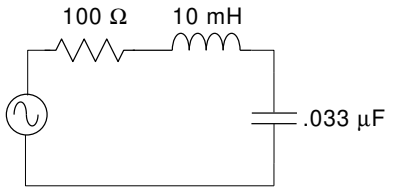


A. out of the page; does not want to flip
B. out of the page; wants to flip
C. into the page; does not want to flip
D. into the page; wants to flip

4. The below plot—similar to that of an oscilloscope—displays voltage vs. time. Such signals may be characterized by the rms voltage (V_{rms}), the period (T), the frequency (f), and the angular frequency (ω). Which of the below is a good estimate of one of these quantities?



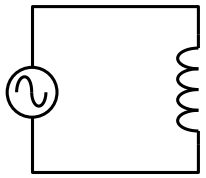
A. $f = 30$ Hz
B. $V_{\text{rms}} = 14$ V
C. $T = .0015$ s
D. $\omega = 2000$ rad/s



5. If an rms AC current of 0.3 A flows through the above circuit, the total electrical power converted to heat is most nearly:

A. 1 W
B. 10 W
C. 100 W
D. Can't say; depends on the frequency of the generator

6. The ac generator in the below circuit has a fixed output voltage (V) and frequency (f). We seek to maximize the current through the coil (which has inductance L). Compared to the simple circuit shown, the current through the coil could be increased by:



A. Adding a resistor in parallel to L
B. Adding a capacitor in series with L
C. Adding an inductor in parallel with L
D. It is not possible to increase the current through the coil by adding components.

7. Rupert is nearsighted: things beyond 2 m look blurry. The proper prescription for Rupert's contact lenses is:

A. -2 D
B. -0.5 D
C. $+0.5$ D
D. $+2$ m

8. The objective of a telescope is described as f/8 with a 30 cm diameter. When an eyepiece with a focal length of 2.4 cm is attached, the angular magnification will (in absolute value) be most nearly

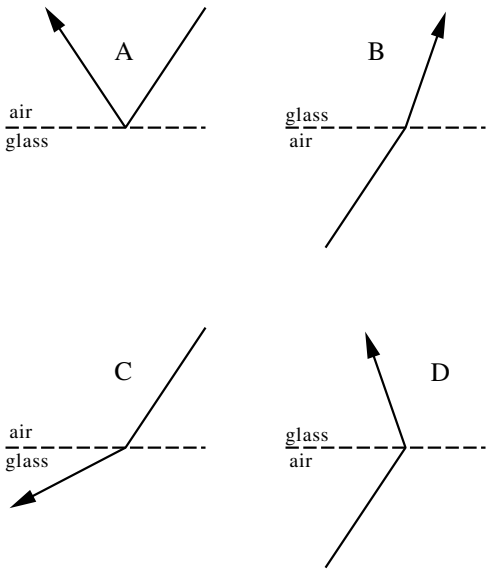
   A. 8×
   B. 30×
   C. 100×
   D. 300×

9. How many of the following statements are true?

   - When using a telescope, the image your eye sees may theoretically be as distant as the stars.
   - When using a microscope, the real image of the objective is generally quite close (say less than 2 inches) from your eye.
   - Theoretically to see fine detail in a microscope you want to use an objective with a large NA.
   - 'Reading glasses' aim to move the image of the book farther way.

   A. 1
   B. 2
   C. 3
   D. 4

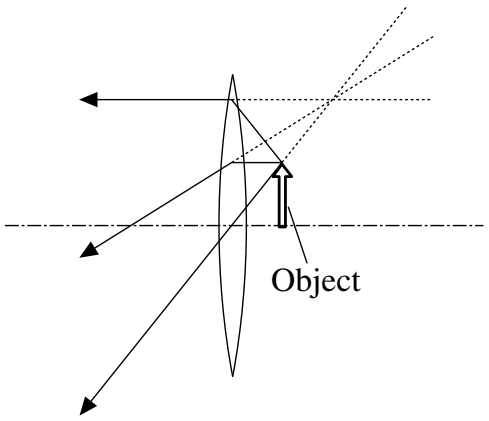
10. Which of the below diagrams properly displays a light ray in air refracted at the interface between air and glass?



11. Which of the following list of types of light correctly orders the light in terms of increasing frequency?

    A. visible, microwave, ultraviolet, X-ray
    B. ultraviolet, visible, infrared, radio
    C. infrared, microwave, ultraviolet, X-ray
    D. radio, microwave, infrared, visible

12. Consider sign convention for situation displayed in the below ray diagram. How many of the the following three quantities: f, p, q are negative?

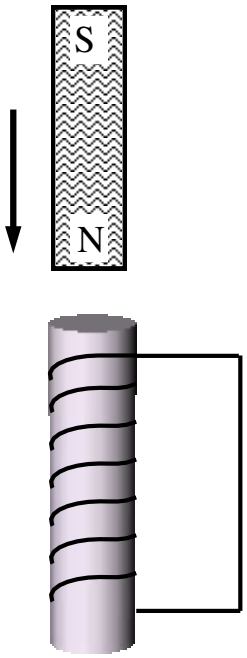


    A. 0
    B. 1
    C. 2
    D. 3

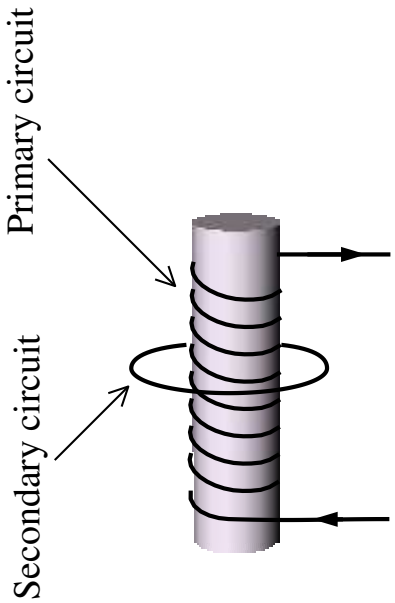
The following questions are worth 12 pts each

Record your steps! (Grade based on method displayed not just numerical result)

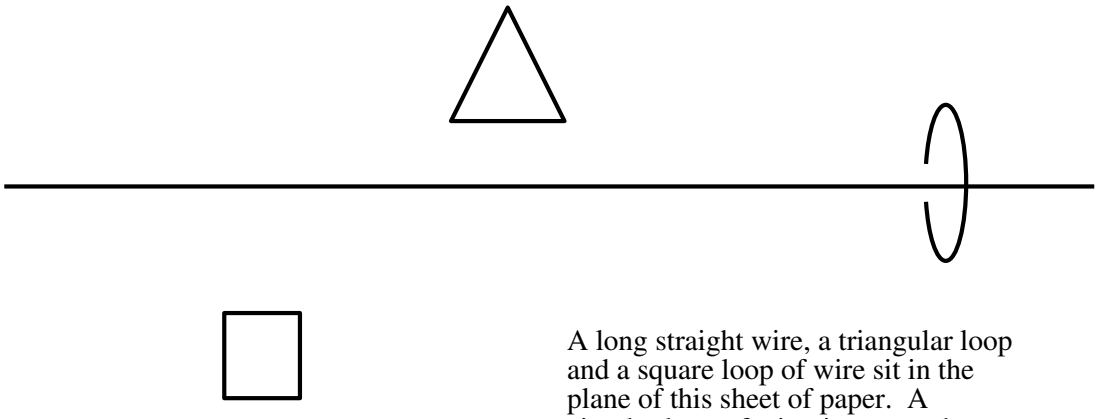
17. The below diagrams show three separate situations with **five** cases of induction. For each case, add an arrow directly on a wire showing the direction of the induced current in that wire. (Note that the bottom case of the long straight wire has three secondary circuits and hence three separate arrows are required.)



The north pole of a bar magnet is approaching the solenoid

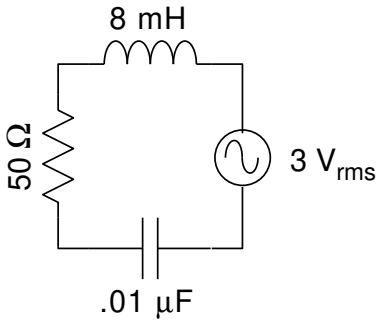


The current shown flowing through the primary circuit is increasing



A long straight wire, a triangular loop and a square loop of wire sit in the plane of this sheet of paper. A circular loop of wire is centered on the long wire, but sits in a plane perpendicular to this sheet of paper. For several minutes there has been no current flowing in any wire. A battery (not shown) is connected and a current starts to flow to the right through the long straight wire.

18. Consider the below right LRC circuit, driven by a generator at a frequency of $f = 20$ kHz

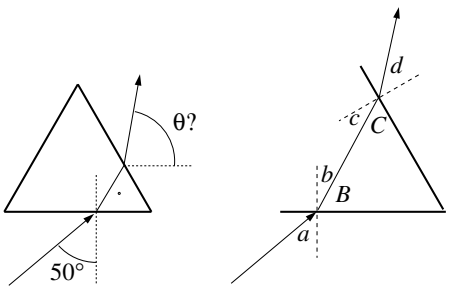


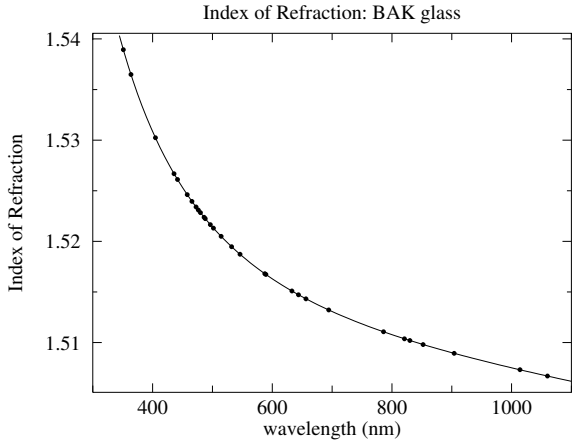
A. What rms current flows through the circuit?

B. What is the rms voltage across the inductor (V_L)? Across the capacitor (V_C)? Across the resistor (V_R)?

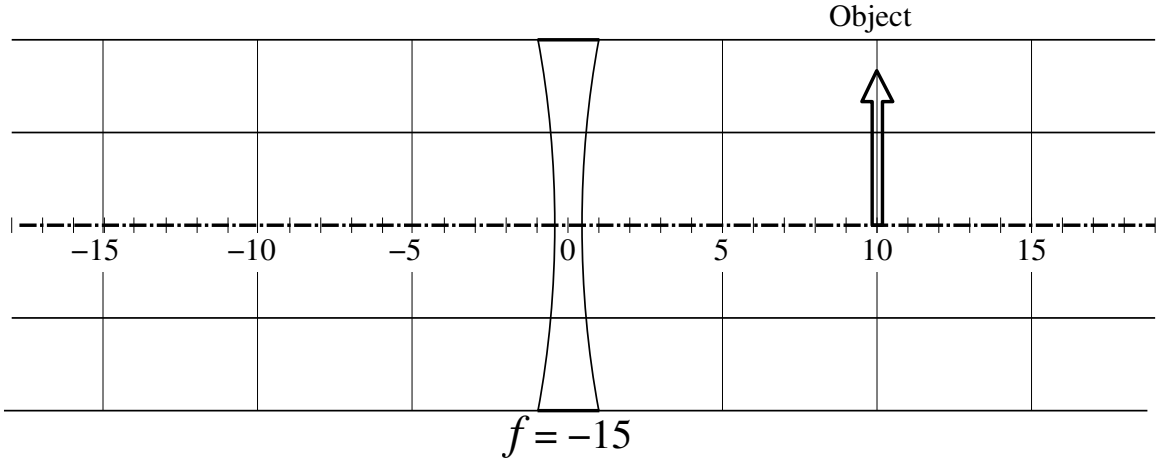
C. Changing only the frequency of the generator, what frequency would produces the largest rms current?

19. As shown in the following diagram, an equilateral (all angles 60°) prism made of BAK glass sits in the air. Light hits the prism at an angle of 50°. The light is a mixture of wavelengths between 400 nm and 800 nm. The index of refraction of BAK glass as a function of wavelength is plotted below. Find the exit angle θ for 400 nm light. Do note that the exit angle θ is defined relative to the horizontal not the normal. (Retain 4 significant digits for this problem.) The rhs diagram shows a expanded view of the light path with angles along the light-path labeled *a,b,c,d*. The angles *B & C* are complementary (add to 90°) with angles *b & c* (respectively). Using the fact that there is a triangle with angles $B, C, 60°$, show that $b + c = 60°$. Starting with $a = 50°$, find the angles b, c, d and finally θ. Would the exit angle θ for 800 nm light be more or less than you calculated for 400 nm light? Report the color of the 400 nm light and the color of the 800 nm light.

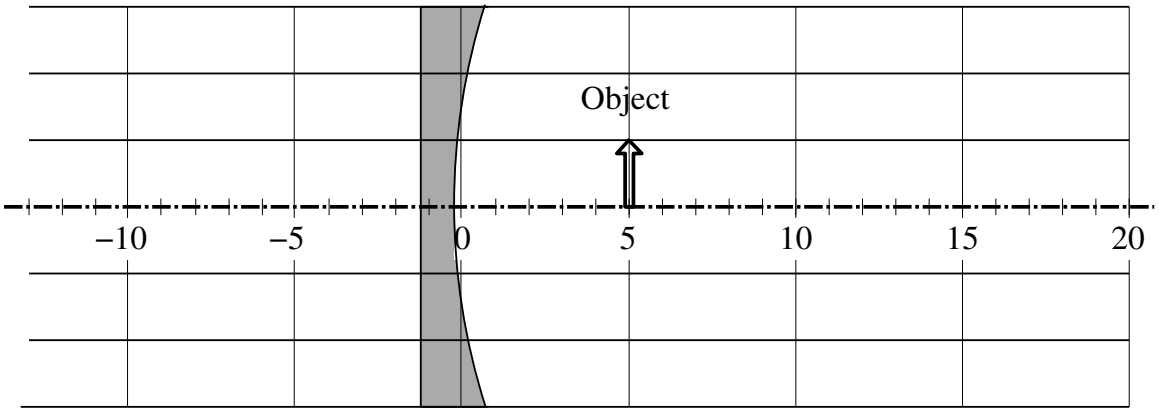




20. Find below two diagrams: a lens & object and a mirror & object. For each situation accurately draw the three and four principal rays described in our textbook. Follow the book's convention: dotted lines for rays extrapolated by the viewing eye and solid line for the actual rays. Draw an arrow accurately showing the size, location and orientation of each image. Draw an eye on each diagram located/oriented so it could see the image.



$f = -15$



$f = +10$