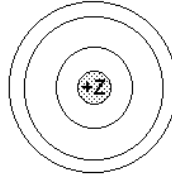


**State Any Assumptions You Need To Make -- Show All Work -- Circle Any Final Answers**  
**Use Your Time Wisely - Work on What You Can - Be Sure to Write Down Equations**  
**BOLDFACE Variables Are Vectors - Feel Free to Ask Any Questions**

**Concepts - Short Answers, etc. (Five words or less) (40,000 points)**

1.) (a) The atom at the right has  $Z$  protons and one electron. What kind of system is this? And of the three electron orbitals shown, mark the one that represents the ground state of the system.



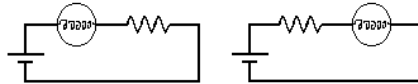
(b) If  $Z > 1$ , why must there be neutrons in the nucleus, along with the  $Z$  protons?

(c) Does a current carrying wire have a net charge? Why or why not?

(d) Use RHR and draw an arrow on each coil below, showing the direction of the **B**-field at the center of each coil.



(e) For the following two circuits, made out of identical bulbs, batteries and resistors, will the bulb be brighter on the left, the right or both the same? Why?



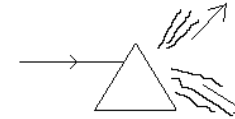
(f) A Physics Final Exam, a magnifying glass and the sun. What's going to happen? And why? And how does the diameter of the magnifying glass make a difference?

**The View From Here (40,000 points)**

2.) Below are two prisms, made of glass with an index of refraction  $n = 1.52$ . The prisms are isosceles triangles, with angles of  $45^\circ-45^\circ-90^\circ$ . (a & b) Show what happens to a laser beam that strikes the center of the faces of each prism, parallel to the base. Calculate all relevant angles and then sketch in all the major rays. (There are things like reflections of reflections that may not be important.)

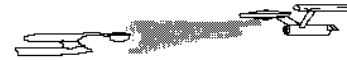


(c) A laser beam shines on the prism, parallel to the base, as shown below. The prism is an equilateral triangles, with angles of  $60^\circ-60^\circ-60^\circ$ . Are the refracted rays bent UP or DOWN in this diagram? Why? (d) Shorter wavelengths of light have a slightly larger index of refraction than longer wavelengths. Does this mean that Blue light is bent MORE or LESS than Red light? Sketch in the letters of the visible spectrum (ROYGBIV) on the refracted rays shown below, to indicate the order of the rainbow of colors from the spectrum.



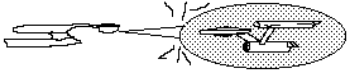
**Star Trek Science (40,000 points)**

3.) (a) As pointed out in class, not everything in science fiction is scientifically accurate. Take *Star Trek*, for example. The *USS Enterprise* (right) can apply a tractor beam on the Klingon warship (left), which applies an attractive force. We can actually make something like a tractor beam, if the *Enterprise* transfers some electrons to the Klingon. (a) If both ships started out as charge neutral, each has a mass of 20,000 metric tons ( $20 \times 10^6$  kg) and are one kilometer (1000 m) apart, find the acceleration between them after  $-5.00$  C of electrons are transferred.



(b) The electrons are accelerated through a potential difference of  $2.20 \times 10^4$  V. Find the speed of the electrons, using  $KE = \frac{1}{2} mv^2$ . Determine if the final speed of the electrons is relativistic. (Don't solve  $KE_{rel} = (\gamma-1) m_0 c^2$ .)

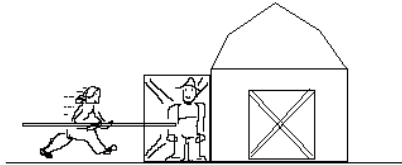
(c) The Klingon warship doesn't like being hit with a tractor beam, so it fires some sort of laser beam at the *Enterprise*. If the frequency of the light is 15.3 EHz ( $E = \text{exa} = 10^{18}$ ), find the wavelength of this light. Is this visible light? ...infrared? UV? radio/microwaves? X-rays or  $\gamma$ -rays?



(d) What is the energy of a single photon of this light?

**The Farmer and the Relatives (40,000 points)**

4.) Here's a classic special relativity problem: A pole vaulter is carrying a 14 foot long pole. A farmer bets the pole vaulter \$50 that the pole vaulter can fit the 14 foot long pole into a 10 foot long barn. Sure that he is about to make a quick \$50, the pole vaulter accepts the bet. The farmer now asks him to run toward the barn at  $v = 0.950 c$ . (a) Determine if the farmer wins the bet from his point of view.



(b) Determine if the pole vaulter wins the bet from his point of view.

(c) Who has the proper time in this problem and what is it?

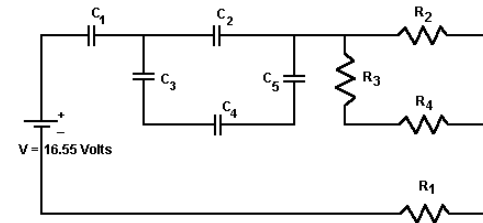
(d) Draw sketches from each P.O.V. of when [I] the front of the pole enters the barn, [II] the rear of the pole enters the barn, [III] the front of the pole leaves the barn and [IV] the rear of the pole leaves the barn. Label them P1, P2, ..., F1, F2,... in the order that the owner of that particular P.O.V. sees the events.

Pole Vaulter's P.O.V.

Farmer's P.O.V.

(e) What can you briefly say as to who wins the \$50?

**The End (40,000 points)**



5.) In the following circuit, all the resistors are  $100 \Omega$  and all the capacitors are  $100 \mu\text{F}$ . (a) What is the equivalent resistance of the group of resistors?

(b) What is the equivalent capacitance of the group of capacitors?

(c) What is the time constant for this circuit?

(d) The initial current is determined by the resistors. Find  $I_0$ .

(e) When the capacitors are fully charged, the voltage across the equivalent capacitor is equal to 16.55 V. What is the voltage drop across any one of the resistors at this time, and why? *Brief answer!*