1. We will start with lightening round, so be prepared to answer lots of short questions about lens/mirrors, eyes, light, refraction, reflection, etc.

2. (20 pts) Consider two "good guy" subs (points A and C), separated by d = 200 m. Between them (at point B) is a "bad guy" sub. All three subs are at a depth h = 300 m. To win the war sub A has to transmit the secret codes to sub C, without the radio signal being detected by the enemy. The captain aims the unidirectional radio transmitter (only sends signal in one direction) at the surface of the water. (n_{air} = 1 and n_{water} = 1.33)

   a) At what angle, θ, relative to the horizontal should the sub captain aim the signal?
   b) There are also many enemy aircraft (Zepplins, etc) that will detect ANY signal that is present in the air above the surface. Has the captain avoided detection and saved the day? Explain.
   c) If at some instant, the magnetic field at sub A's transmitter is directed out of the page, show the direction of the electric field on the diagram. Justify your answer.
   d) How long does it take the signal to reach sub C?
   e) If the sub A broadcasts a signal with a frequency of 80 Mhz,
      - What is the wavelength of the signal reaching sub C?
      - What frequency should the zepplin receiver's be looking for in the air?

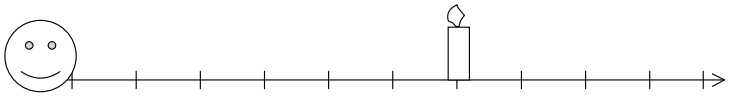
3. (20 pts) In the movie Batman Begins, the bad guys have a high power microwave generator they use to vaporize a city's water supply. My questions are these

   a) Explain why microwaves could heat up water. (Hint: water molecules have one side positive and one side negative, i.e. an electric dipole)
   b) If the bad guys use a 5 m diameter beam of microwaves to heat up 10^6 kg of water from room temperature (20° C) to the boiling point (100° C) in 30 seconds, What is the intensity of the microwave beam? The specific heat of water is 4190 J/(kg K). (NOTE: this of course only raises the temp of water to boiling point, would need more energy to vaporize it)
   c) What is the amplitude of the magnetic field of the microwave beam in part b?
   d) In the original script, Batman realizes that as the beam travels to the right, the magnetic field always points into and out of the page. What is the polarization direction when the magnetic field points into the page?
   e) Batman has two polarizers glued together with their axes 45 degrees apart.
      - If the axes of the FIRST polarizer matches the polarization axis of the beam, by what fraction will Batman reduce the intensity?
      - If the axes of the SECOND polarizer matches the polarization axis of the beam, by what fraction will Batman reduce the intensity?
      - Is it possible for Batman to use this double polaraizer to completely block the beam? Explain.

4. It is 1974 and you are shopping for 2m long snow skis. Your feet attach to the middle of the skis. You try them on and stand 3m in front of a mirror. The mirror goes from the very high ceiling to 0.5m above the floor. Your head is 2m above the ground.
   a) Draw a picture of this.
   b) Explain how you can see your feet even though the mirror does not go all the way to the ground.
   c) The skis are very expensive, so you want your friend's opinion…but it is 1974, so you can't just take a cell phone picture and send it off, you will have to use a real camera and take a picture of the front tips of the skis in the mirror. (and wait for the film to be developed, etc). What distance should your camera be adjusted to take a clear picture of the front tips in the mirror? And at what angle (relative to the horizontal) should you aim the camera so you can see the front tips of the skis in the mirror? Explain. (You may assume the camera is right at your head location.)

5. (20 pts) A 4 cm tall candle is placed at x = 12 cm. A diverging mirror with $|f_1| = 12$ cm is placed at x = 24 cm. A converging lens with $|f_2| = 6$ cm is placed at x = 0 cm. (Note: Mirror and lens are not shown.) You position yourself as shown and are looking at this arrangement from the far left side. Answer the following

   - How many candle images do you see from your location? (Hint: think about how light gets from the candle to you.)
   - For each candle image you see, please provide the exact x-location of the image, whether image is same orientation as candle or inverted, whether the image is bigger, smaller, or same size as the candle. Justify your answers.
   - Show the formation of the images you see by ray tracing. Show a separate diagram for each image you see, to avoid confusion. I have provided several copies of the picture on the next page for your diagrams.



I have provided several copies, use only as many as you need. i.e. I am NOT saying you will need this many.