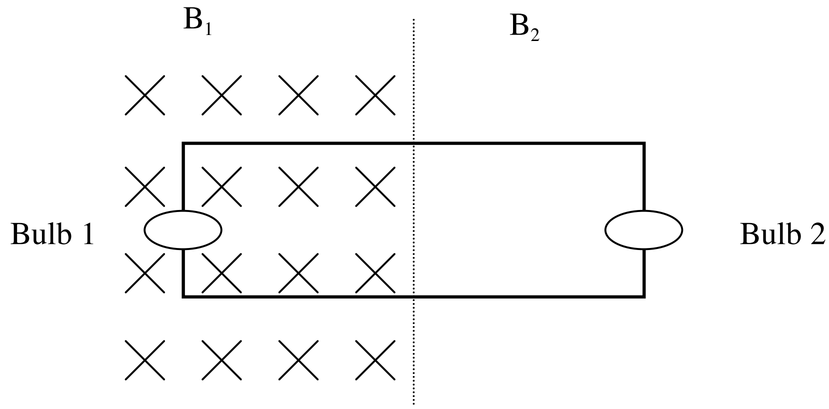
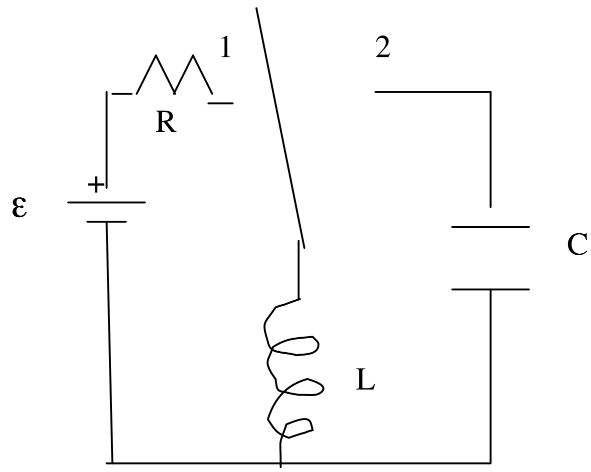
1. A rectangular metal loop (width = 2 m and height = 1 m) is sitting in a divided region of space. The left half is in a region of magnetic field B_1=4 Tesla directed into the page. The right half is in a region where the magnetic field is $B_2=4t^2$ Tesla directed out of the page (t is in seconds). The situation is shown at t=0 s. The loop has two light bulbs (resistances, R_1= 1Ω, R_2= 2Ω) in it as shown.



a) At t = 1 s, find the direction of the current (if any) in each bulb. Specify up, down or zero. Explain.
b) At t = 1 s, find the magnitude of the current (if any) in each bulb.
c) At t = 1 s, find the direction of the net force on the loop (assuming the loop is free to move at that time)

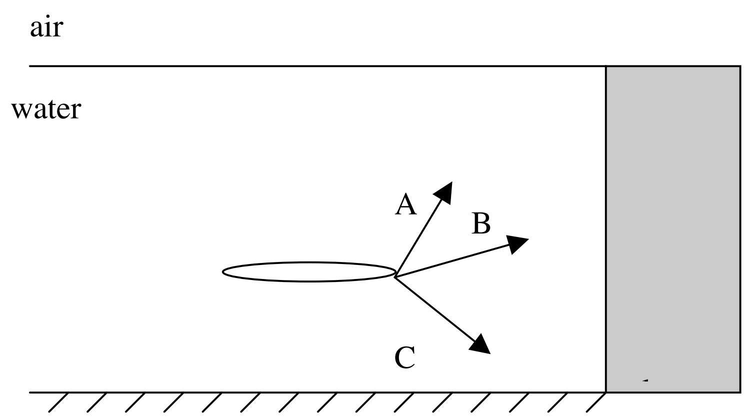
2. For the circuit shown $R = 2\ \Omega$, $L = 8$ H, $C = 2$ F, and $\varepsilon = 12$ V. At time $t = 0$ s the switch is thrown to position 1. At time $t = 32$ s, the switch is thrown to position 2.



a) What is the maximum current in the inductor?
b) What is the maximum charge on the capacitor? When is the first time this occurs? And which plate is positive?
c) What is the maximum voltage across the inductor?
d) Sketch the graph the current through the inductor and the voltage across the inductor as a function of time (starting at $t = 0$).

3. In the first Austin Powers movie, Dr. Evil wants sharks with laser beams strapped to their heads. Suppose he has one in a tank of water (n_w = 1.33) that has a mirrored bottom and 10 cm thick glass walls (n_g = 1.5). The shark can look in one of 3 directions shown in the diagram. Determine (and show clearly on a sketch) at what angle the ray emerges into the air for

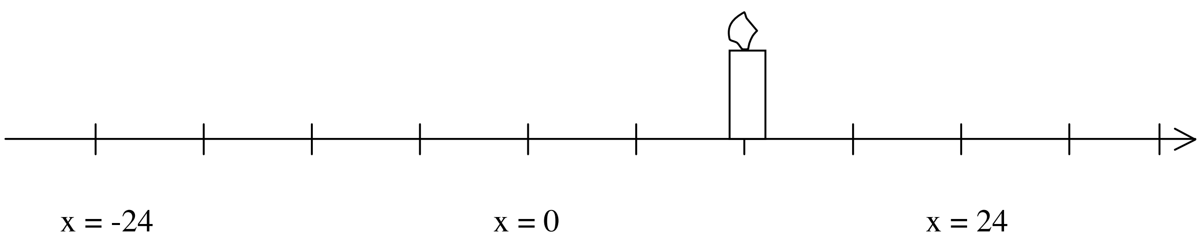
   a) Ray A (initially 70 degrees above the horizontal)
   b) Ray B (initially 20 degrees above the horizontal)
   c) Ray C (initially 50 degrees below the horizontal)
   d) At some instant in time the electric field vector for ray A at the tip of the shark is directed into the page, what direction is the magnetic field? Explain



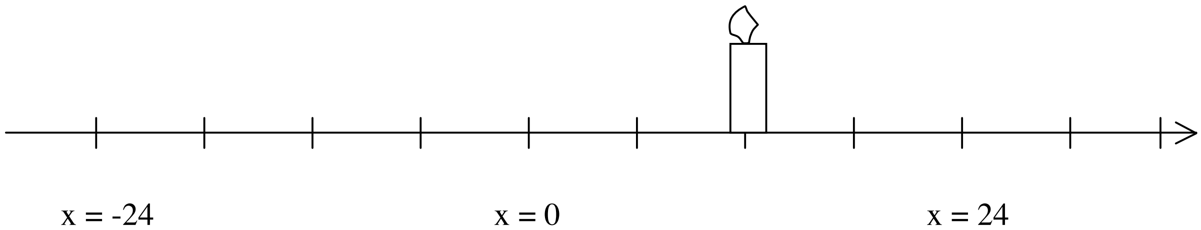
4. A 4 cm tall candle is placed at x = 12 cm. A diverging mirror with $|f_1| = 12$ cm is placed at x = 24 cm. A converging lens with $|f_2| = 6$ cm is placed at x = 0 cm. (Note: Mirror and lens are not shown.) Answer the following

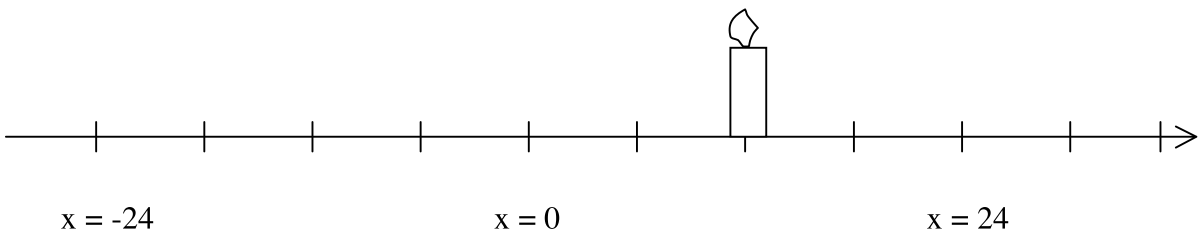
   (Hint: think about in what direction light radiates from the candle.)

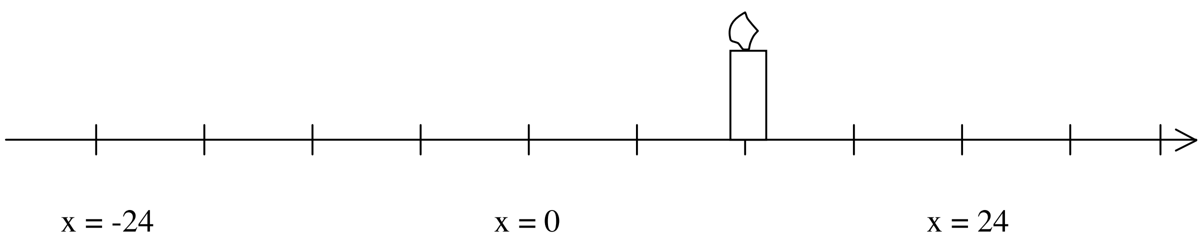
   - At what location (or locations) can you hold a screen and detect a clear image of the candle? For each candle image, please provide the exact x-location of the image, whether image is same orientation as candle or inverted, whether the image is bigger, smaller, or same size as the candle. Justify your answers.
   - Show the formation of the images by ray tracing. Show a separate diagram for each image, to avoid confusion. I have provided several copies of the picture on the next page for your diagrams.

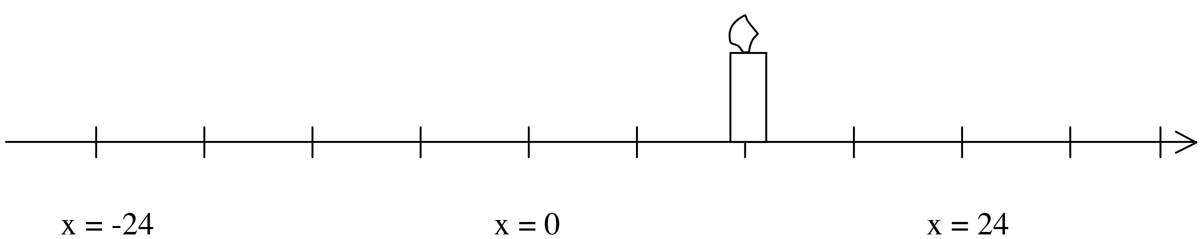


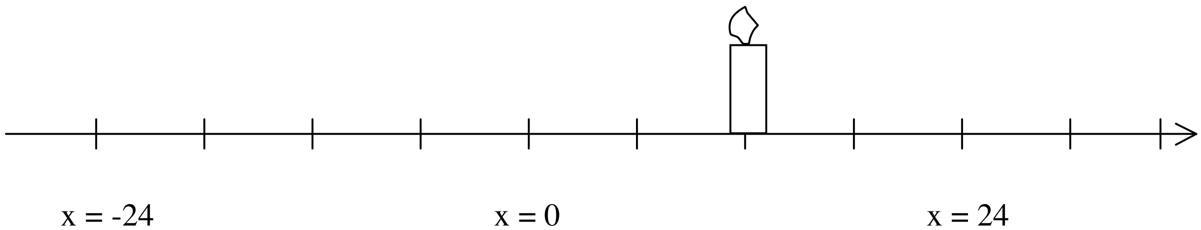
I have provided several copies, use only as many as you need. i.e. I am NOT saying you will need this many.











5. Orange light, wavelength 600 nm, is incident on a vertical slit of width, 0.1 mm. A square screen (0.2m x 0.2m) is centered a distance 2m behind the slit. A light sensor can be positioned anywhere on the screen.

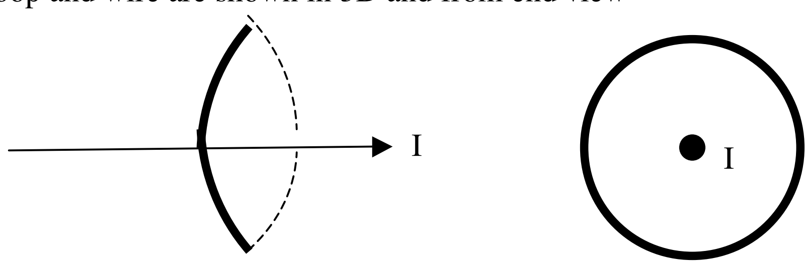
a) If the light sensor measures an intensity of 0.1 mW at the center of the screen, what are the amplitudes of the electric and magnetic fields at that location?
b) At what location or locations (measured from the central axis) will a light sensor, on the screen, register zero intensity? State whether you are measuring horizontally or vertically from the central axis.
c) As the slit size is continually increased, will the number of zero intensity locations found on the screen increase, decrease or stay the same? Explain.
d) As the screen is continually brought closer to the slit, will the number of zero intensity locations found on the screen increase, decrease or stay the same? Explain.
e) As the frequency of the light is decreased will the number of zero intensity locations found on the screen increase, decrease or stay the same? Explain.
f) A blue light, wavelength 450 nm, is now turned on (the orange light is also on). At what location or locations (measured from the central axis) will a light sensor, on the screen, register zero intensity?

Lightning Round

I. Which of the following can NOT be the instantaneous electric and magnetic fields of an EM wave coming out of the paper toward you.

(a) (b) (c) (d)

II. Consider a long horizontal wire carrying current I in direction shown. The wire is surrounded by a concentric metal loop of resistance R. The loop and wire are shown in 3D and from end view



End view

If the current in the wire increases from I to 3I, which increases in magnitude?

a) $\int$ **B • ds** around the loop

b) $\int$ **B • dA** through the loop

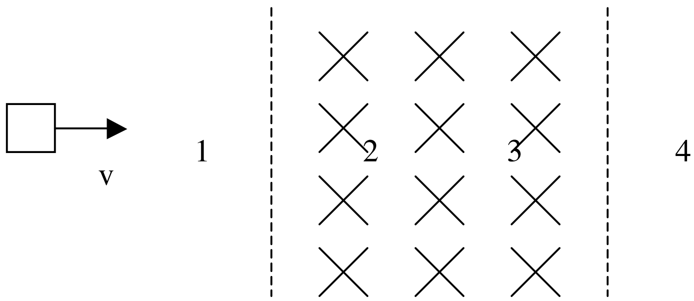
c) The current induced in the loop
d) Both (a) and (c)

III. IF Terry reads this test while wearing his glasses (diverging lens), the image of the word IF appears on his retina as

(a) (b) (c) (d)

Questions IV – VI concern the following scenario.

A loop with area, A, and resistance, R, is shot, with initial velocity, v, into a region of uniform magnetic field, B, directed into the paper as shown. Four locations are shown 1,2,3,4



B

Answer T or F (for True or False)

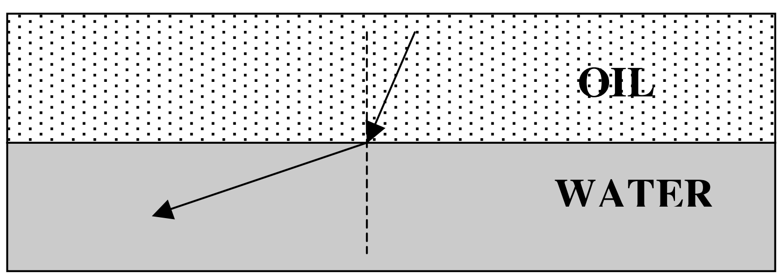
IV. As the loop moves from 1 to 2, a counter-clockwise current is induced

V. As the loop moves from 2 to 3, a counter-clockwise current is induced

VI. The loop slows down as it enters the B-field (from 1 to 2) and it speeds up as it exits the B-field (from 3 to 4).

Questions VII – VIII concern the following scenario.

Consider light passing through an oil slick on the top of the ocean. The light ray bends as shown.



Answer T or F (for True or False)

VII. Comparing the indices of refraction, $n_{oil} > n_{water}$

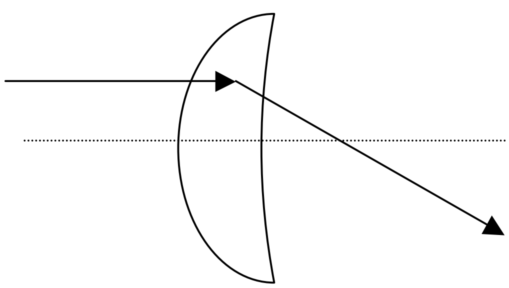
VIII. Comparing the frequency of light, $f_{oil} > f_{water}$

IX. For a double slit experiment performed with red light, bright fringes are found at y = …, -6 cm, -4 cm, -2 cm, 0 cm , 2 cm, 4 cm, 6 cm, … as measured from the central axis. Which results in the fringes being closer together.

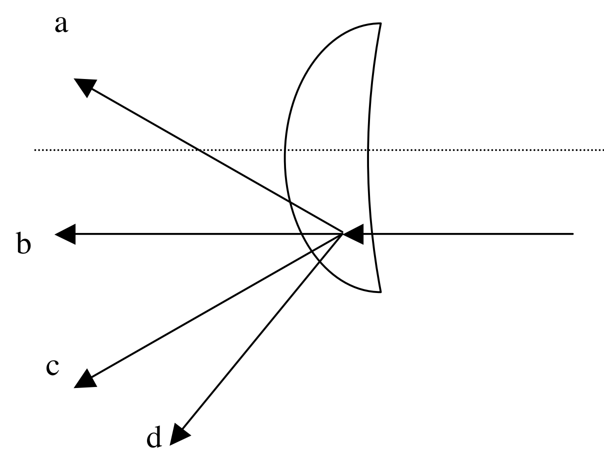
a) Move the slits closer together
b) Perform the experiment with blue light
c) Both (a) and (b)
d) Neither (a) nor (b)

X. Consider a lens which is neither double convex nor double concave. Assuming the ray drawn in (1) is the correct overall refraction for light passing through this thin lens in the direction shown. Which ray is the correct ray for light passing through this lens in the other direction (figure (2))

(1)



(2)



XI. For a thin coating (n_{coat} = 1.4) on my glasses (n_{gl} = 1.5), which thickness will minimize reflections for green light, λ_{green}.

a) $t = \lambda_{green}/(4\ n_{coat})$
b) $t = \lambda_{green}/(4\ n_{gl})$
c) $t = \lambda_{green}/(2\ n_{coat})$
d) $t = \lambda_{green}/(2\ n_{gl})$