Name: ______________________________

You may answer the questions in the space provided here, or if you prefer, on your own notebook paper.

Short answers

1. 5 points What was Maxwell's finding that related light to electromagnetic waves?

2. 5 points List at least two things that suggest that light is a wave, and then list one key thing that suggest light is particle.

3. 5 points What are the two principles of relativity?

4. 5 points What radical realizations about space and time did relativity theory bring about?

5. 5 points What happens when we shine a laser through a double slit apperatus? What will we see on a screen behind the laser? What happens if instead of a beam of light, we only send one photon at a time?

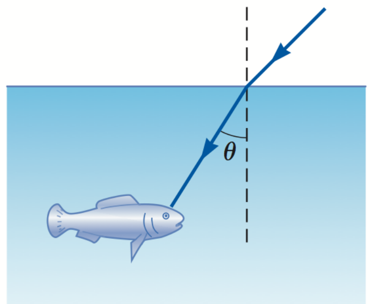
Please go on to the next page. . .

Problems

6. 15 points A sinusoidal planer electromagnetic wave with frequency 30.0×10^6 Hz, in free space, traveling in the x direction has a maximum electric field amplitude of $150\hat{\mathbf{j}}$ N/C.

   (a) Find the wavelength and period of the wave.

7. 10 points Suppose you are a bird hunting for fish. You like a particular species of fish that has evolved to dive deeper when it spots you, so you want to be quick to capture it. If the fish is 0.30 m below the surface of water, and you are gliding just above the surface of the water, how close (in the horizontal direction, and in terms of total distance) can you get to the fish before it spots you? **Given:** $n_{air} = 1$, $n_{H_2O} = 1.33$



8. 10 points Suppose we have a thin film with index $n = 1.33$ and thickness $t = 113nm$. What maximum wavelength of light would result in constructive interference.

9. 15 points When monochromatic ultraviolet light that has a wavelength equal to 400.0 nm is incident on a sample of an unknown metal, the emitted electrons have a maximum kinetic energy of 3.03 eV. **Given:** $hc = 1240\mathbf{eV \cdot nm}$.

(a) What is the energy of an incident photon?

(b) What is the work function for potassium?

(c) What would be the maximum kinetic energy of the electrons if the incident electromagnetic radiation had a wavelength of 600.0 nm?

(d) What is the maximum wavelength of incident electromagnetic radiation that will result in the photelectric emission of electrons by a sample of potassium?

10. Suppose you are orbiting the black hole at the center of our galaxy, Sgr A*, and you are 139.3×10^{10} km away from the center of the black hole. You are broadcasting a radio station at 107.5 MhZ, 107.5 on the FM Dial of an old style car radio. Your friend is orbiting much much closer to the black hole at 1.6×10^{10} km away from the center of the blackhole. Your friend scans the radio-frequencies looking for your channel.

    Given: Sgr A* has a mass of 4.31×10^{6} times that of the sun, the sun's mass is 1.988×10^{30} kg. Other constants can be found in your homework from Week 3 which should be very helpful here.

    (a) Assuming you are both circling in perfectly circular orbits, what is your velocity as you travel around the Black Hole?

    (b) Find your friend's velocity as well.

    (c) Just using these two velocities and ignoring the complexities involved (in other words, just use the two velocities above and don't worry about the fact that the relative velocity between you and your friend varies depending on where each observer is at in their orbits), find the frequency shift due to special relativity. Use your frame as the rest frame.

    (d) Find the frequency shift due to General Relativity.

(e) At what frequency will your friend find your channel?

(f) Your friend is dangerously close to the Event Horizon of Sgr A*. What happens if they get too close?

(g) Say that you orbit for an entire year. Did your friend measure more time or less time than you did? Who is older? Why?

Some possibly useful equations.

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$

$$I = S_{avg} = \frac{E_{max}^2}{2\mu_0 c}$$

$$B = \frac{E}{c}$$

$$c = \lambda f$$

$$c^2 = a^2 + b^2$$

$$T = \frac{1}{f}$$

$$\mu_0 = \left(4 \times \pi \times 10^{-7} \text{Tm/A}\right)$$

$$\frac{\Delta f}{f} = \frac{\Delta U_g}{m_s c^2}$$

$$c = \left(2.99 \times 10^8\right) \frac{\text{m}}{\text{s}}$$

$$2nt = \left(m + \frac{1}{2}\right) \lambda, m = 0, 1, 2 \ldots$$

$$E = \frac{hc}{\lambda}$$

$$KE = E_{photon} - \phi$$

$$hc = 1240 \text{eV} \cdot \text{nm}$$

$$m_p = 1.672 \times 10^{-27} \text{ kg}$$

$$q_p = 1.602 \times 10^{-19} \text{ C}$$

$$m_e c^2 = 0.511 \text{ MeV}$$

$$K = \gamma m c^2$$

$$K = E - mc^2$$

$$E^2 = p^2 c^2 + (m_p c^2)^2$$

$$x' = \gamma(x - vt)$$

$$t' = \gamma(t - \frac{vx}{c^2})$$

$$L' = \frac{L_p}{\gamma}$$

$$t' = \gamma t_p$$

$$U_g = -\frac{G M_E m}{r}$$

$$\Delta U_g = U_g(r_f) - U_g(r_i)$$