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?

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Problems

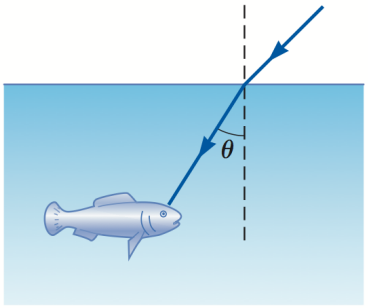
6. [15 points] A sinusoidal planer electromagnetic wave with frequency 30.0×10^6 Hz, in free space, traveling in the x direction has a maximum electric field amplitude of $150\hat{\mathbf{j}}$ N/C. Recall that in sinusoidal planer waves, the **E** and **B** fields are perpendicular to each other, and to the direction of motion.

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

   (b) Find the maximum amplitude and direction of the magnetic field of the wave.

   (c) Find the average value of the intensity 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:** $hc = 1240\mathbf{eV} \cdot \mathbf{nm}$.

   (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. [15 points] (a) [2 points] Find the rest energy of a proton in units of electron volts. Given: $m_p = 1.672 \times 10^{-27}$ kg, $c = (2.99 \times 10^8)\,\frac{\mathrm{m}}{\mathrm{s}}$, $1.00eV = 1.602 \times 10^{-19}J$.

(b) [2 points] If the total energy of a proton is 5.0 its rest energy, what is the speed of the proton relative to the lab from which it is launched?

(c) [2 points] An event taking place in the proton's rest frame is clocked at 14.0 s, how long would that event seem to take in the lab frame? *Hint: The shortest time you can measure is in the rest frame*

(d) [2 points] Determine the kinetic energy of this proton in units of electron volts.

(e) [2 points] What is the proton's momentum?

Some possibly useful equations.

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

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

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

$$c = \lambda f$$

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

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

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

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

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

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

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

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

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

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

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

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

$$K = E - mc^2$$

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

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

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

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

$$t' = \gamma t_p$$