

Begin your response to **QUESTION 4** on this page.

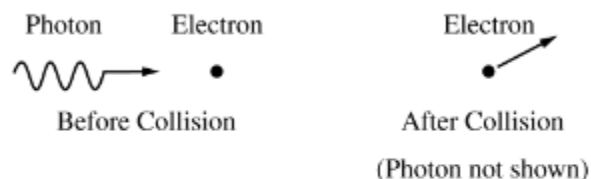
4. (10 points, suggested time 20 minutes)

Light and matter can be modeled as waves or as particles. Some phenomena can be explained using the wave model, and others can be explained using the particle model.

(a) Calculate the speed, in m/s, of an electron that has a wavelength of 5.0 nm.

(b) The electron is moving with the speed calculated in part (a) when it collides with a positron that is at rest. A positron is a particle identical to an electron except that its charge is positive. The two particles annihilate each other, producing photons. Calculate the total energy of the photons.

Continue your response to **QUESTION 4** on this page.



(c) A photon approaches an electron at rest, as shown above on the left, and collides elastically with the electron. After the collision, the electron moves toward the top of the page and to the right, as shown above on the right, at a known speed and angle. In a coherent, paragraph-length response, indicate a possible direction for the photon that exists after the collision and its frequency compared to that of the original photon. Describe the application of physics principles that can be used to determine the direction of motion and frequency of the photon that exists after the collision.