Quiz 1: Modern Physics

Date: 20 **Feb.** 2018

Use the following values where needed.

$$\begin{aligned} \text{Plancks constant} = h &= 6.63 \times 10^{-34} \text{ Js} \\ \text{Charge on electron} = e &= 1.6 \times 10^{-19} \text{ C} \\ \text{mass of electron} = m_e &= 9.1 \times 10^{-31} \text{ kg} \\ 1 \text{ eV} &= 1.6 \times 10^{-19} \text{ J}. \end{aligned}$$

1. The wave function of a free electron is,

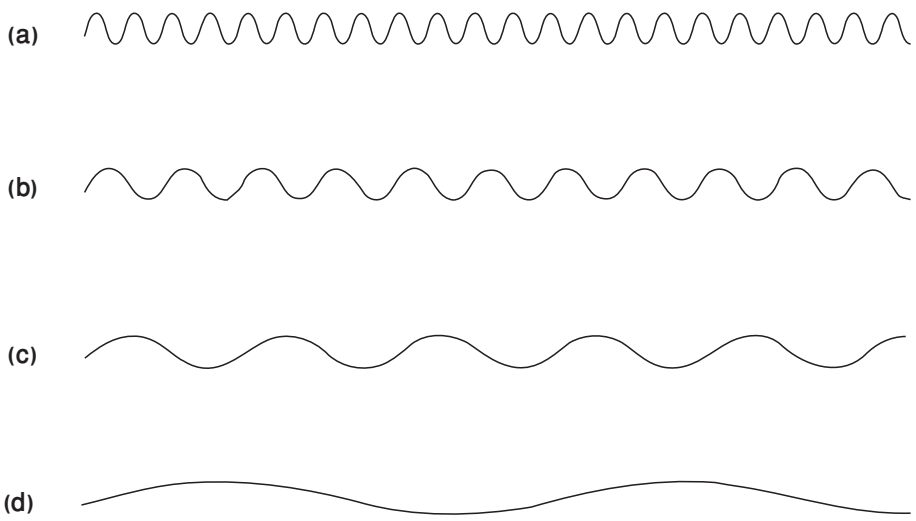
   $$\psi(x) = Ae^{i(10^{10}\,x)},$$

   where x is in meters. Calculate,
   (a) the de Broglie wavelength,
   (b) its momentum,
   (c) its kinetic energy,
   (d) uncertainty in position and momentum.

2. A γ ray photon has five times the energy of an X ray photon. What can be said about their wavelengths?
   (a) We cannot say anything because we have no clue about their relative frequencies.
   (b) $\lambda_{\gamma\text{ray}} = 5\lambda_{X\text{ray}}$.
   (c) $\lambda_{\gamma\text{ray}} = \lambda_{X\text{ray}}/5$.
   (d) $\lambda_{\gamma\text{ray}} = \lambda_{X\text{ray}}$.
   (e) $\lambda_{\gamma\text{ray}} = \left(\lambda_{X\text{ray}}\right)^2$.

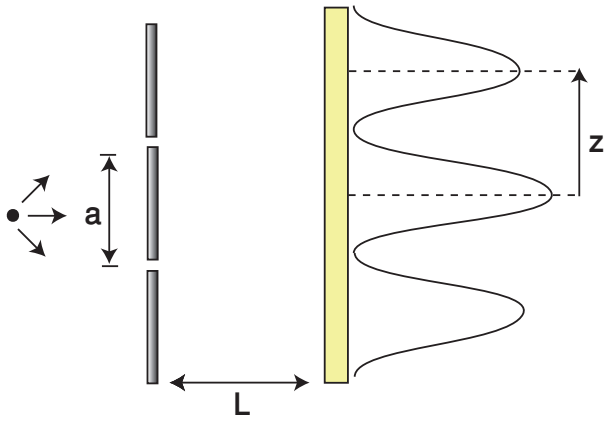
3. Muons are particles 200 times heavier than electrons. A muon and electron have identical kinetic energies. What can you say about their wavelengths λ?
   (a) Both have the same wavelength λ, i.e., $\lambda_{\text{muon}} = \lambda_{\text{electron}}$.
   (b) $\lambda_{\text{muon}} > \lambda_{\text{electron}}$
   (c) $\lambda_{\text{muon}} < \lambda_{\text{electron}}$
   (d) The muons do not have a de Broglie wavelength.

4. The accompanying figure shows the (real part) of the wavefunctions (fields ψ) of four particles in space. Which one of these has the highest momentum p? The horizontal axis is distance.



(e) **The figures are inconclusive.**

5. Refer to the accompanying figure.



Particles of momentum p_0 enter the double-slit experiment. Assume $L \gg a$, $L \gg z$, where z is the distance between the central maximum and the position of the first maximum. What is z?

(a) hL/ap_0

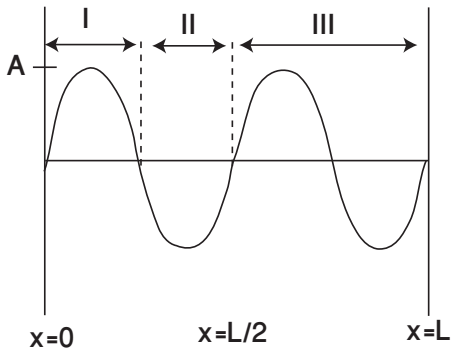
(b) ahL/p_0

(c) hLp_0/a

(d) hL/a

(e) p_0a/hL.

6.



The figure shows the wave function of a particle $\psi(x)$. The wave function is real and is zero at $x \geq L$ and $x \leq 0$. The wave function in the region $x \in [0, L]$ is:

(a) $A \sin\left(\frac{4\pi x}{L}\right)$

(b) $A \sin\left(\frac{\pi x}{L}\right)$

(c) $-A \sin\left(\frac{4\pi x}{L}\right)$

(d) $A \sin\left(\frac{2\pi x}{L}\right)$

(e) $A \sin\left(\frac{2\pi}{L}\right)$

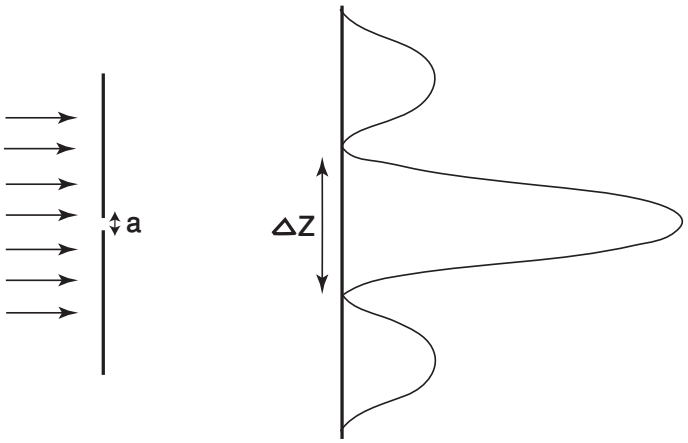
7. Suppose $P(I)$ represents the probability of locating the particle in region I. These regions I, II, and III are shown in the diagram of Q6. Write **True** or **False** in front of these sentences.

(a) $P(I) > P(II)$

(b) $P(I) + P(II) < P(III)$

(c) $P(I) < P(III)$.

8.



The figure shows the profile of intensity from a stream of electrons incident on a single slit. Δz is the width of the first fringe and a is the slit width. If the experiment is repeated with muons ($m_{\text{muon}} = 200\ m_{\text{electron}}$) of the same energy, what happens to the width of the central peak? Ignore the charge on these particles

(a) Δz remains unchanged.

(b) Δz increases 200 times.

(c) Δz decreases 200 times.

(d) Δz increases $\sqrt{200}$ times.

(e) Δz decreases $\sqrt{200}$ times.

9. One wishes to measure the K.E. of an electron whose speed is 10.0 m/s with an uncertainty in energy of no more that 0.1%. How much time is needed to make the measurement? (Hint: Use $\Delta E \Delta t \geq \hbar/2$).

(a) ≈ 1 s

(b) ≈ 10 s

(c) ≈ 1 ms

(d) ≈ 10 ms

(e) insufficient information is provided.