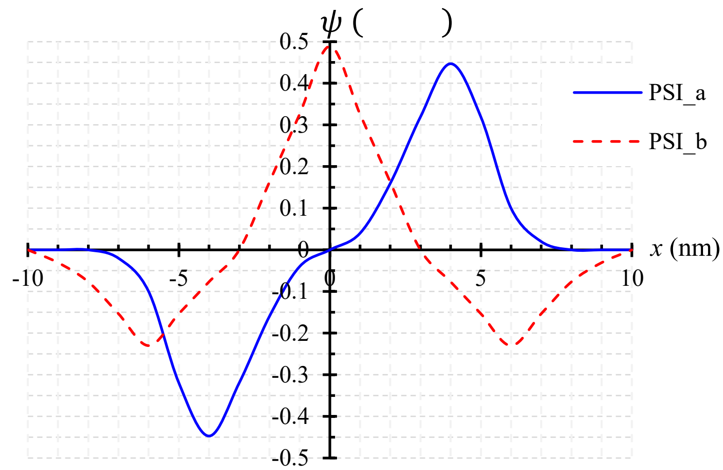
****1) Briefly explain Compton scattering. Include a comment on the historical significance.

A scientist at rest (frame 1) observes a particle travel 1.000 m in a straight line for 6.01 ns before decaying. Assume frame 2 is travels along with the particle with the same speed as the particle.
2a) Determine the speed of the particle in frame 1. Answer in terms of c.
2b) Which frame records the proper time for time to decay?
2c) Determine time to decay in frame 2.

A wavefunction is given by $\psi(x) = Axe^{-kx^2}$ over the interval $-\infty < x < +\infty$.
***3a) Determine the normalization constant A.
***3b) Determine the expectation values of position & momentum.
***3c) Determine the most probable position.
Do some particle in a box problems, too! 39.3, 39.4, 39.5, 39.9,

The following questions refer to the graph at right. Assume ψ_a is a wavefunction for a particle in energy level A while ψ_b, is a wavefunction for a particle in energy level B.

4a) What units should we assume on the vertical axis for ψ? Label the vertical axis appropriately.



4b) Which wavefunction corresponds to a higher energy level?

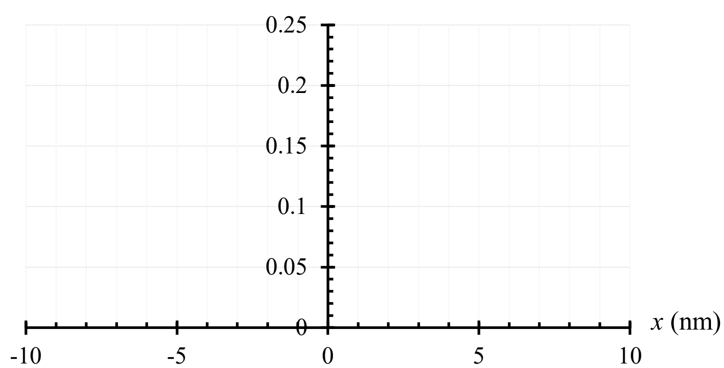
impossible to determine $\boldsymbol{\psi_a}$ $\boldsymbol{\psi_b}$ **same energy**

4c) Which particle(s) has(have) a negative probability of being found at position x=+5 nm?

both $\boldsymbol{\psi_a}$ $\boldsymbol{\psi_b}$ **neither impossible to determine**

4d) Sketch a plausible graph of the probability density for energy level A. The wave functions are *approximately* normalized. It is ok for you to assume they are *perfectly* normalized.
Include a vertical axis label with units!!!

4e) For a particle with wavefunction ψ_b, estimate the most likely position(s) & 2nd-most likely position(s) to experimentally observe the particle.



******5) An electron in a hydrogen atom *emits* a photon with energy 0.3763 eV and winds up in the 5th energy level. Determine the *initial* energy level, the *photon* wavelength, and the de Broglie wavelength *of the electron* in the final state.

n_i	
λ_γ	
λ_e	

You should also practice deriving energy levels of the Bohr model (workbook problem **38.13**). Be aware of key terms on the equation sheet for this derivation.

(6) The following questions refer to a hydrogen atom modeled by the Bohr Model.

a) As we go to higher energy states, what happens to the spacing of adjacent *radii*?

Radii are equally spaced as $n \to \infty$	Radii get closer together as $n \to \infty$	Radii get farther apart as $n \to \infty$	Impossible to determine without more info

b) As we go to higher energy states, what happens to the spacing of adjacent *energy levels*?

Energy levels are equally spaced as $n \to \infty$	Energy levels get closer together as $n \to \infty$	Energy levels get farther apart as $n \to \infty$	Impossible to determine without more info

c) How much energy must an atom in the ground state ($n = 1$) absorb to ionize (electron escapes atom)?

About 0.85 eV	About 12.1 eV	About 13.6 eV	Impossible to determine without more info

d) What happens to the energy required to ionize the atom if the atom starts in a higher energy state?

Requires *more* energy compared to part c.	Requires *the same* energy as in part c.	Requires *less* energy compared to part c.	Impossible to determine without more info

e) Can a hydrogen atom in the ground state absorb a 14.0 eV photon? If so, what happens?

The photon cannot be absorbed because the energy doesn't match any transitions.	The photon is absorbed but the extra 0.4 eV is lost.	The photon is absorbed. The extra 0.4 eV goes into kinetic energy of particles.	Impossible to determine without more info

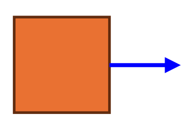
A slab of metal emits electrons when exposed to 275 nm light. The maximum observed speed of emitted electrons is 0.123% of light speed (in vacuum). Assume relativistic corrections are negligible.

**7a) Determine the work function of the metal.

7b) If the *intensity* of incident light is decreased, how is the max electron speed affected?

7c) If the *wavelength* of incident light is decreased (instead of intensity), how is the max electron speed affected?

A rectangular plate is travels to the right at $0.9165c$. An observer at rest observes the plate is a perfect square with side length 0.888 m. A second observer in a spaceship moves parallel to the plate with the same speed as the plate.



8a) Should the second observer measure a larger or smaller area for the plate?

**8b) Determine numerical values of the plate's dimensions for the second observer.

***9) What wavelength of light experiences a 1% wavelength shift due after Compton scattering at 45°?

10) The wavefunction 2s state of hydrogen is listed below.

$$\psi_{2\,0\,0} = \frac{1}{4\sqrt{2\pi a_0^3}}\left(2 - \frac{r}{a_0}\right)e^{-r/2a_0}$$

a) Show this wave function is normalized.
b) Show work to determine the most probable radius. This is a hard one. Instead of trying to *finish* this problem, verify you *started* the problem the correct way for each part and trust in your ability to do math. Stop after you've reached a polynomial.

11) What is the largest & smallest possible angular momentum quantum number for a hydrogen atom in the $n = 7$ state? What if I had asked for the largest & smallest possible values of the quantum number relating to z-component of angular momentum instead?

****12) An observer at rest sees one spaceship 1 moving to the right with speed $0.300c$ and spaceship 2 moving to the left with speed $0.400c$. What speed does ship 1 observe for ship 2?

*13) A proton and electron travel with the same speed. Which is has a longer wavelength? Is it a tie? Explain.

****14) Consider a proton of mass confined in a nucleus of diameter 22.2 fm $= 2.22 \times 10^{-14}$ m.

a) Determine the minimum uncertainty in this proton's momentum.
b) Determine the minimum uncertainty in the proton's speed.
c) Redo the previous two parts for an electron of mass in an atom of diameter $5.24a_0$.

*****15) The rest mass of a proton is 1.673×10^{-27} kg. The total energy of this proton is 4.00 times its rest mass.

a) Determine rest energy of the proton in units of eV using engineering notation with best choice of prefix.
b) Determine use the determined value of rest energy to express mass of the proton in units of $\frac{\text{MeV}}{\text{c}^2}$.
c) Determine speed of the proton in units of $\frac{\text{m}}{\text{s}}$ and in the dimensionless form β.
d) Determine kinetic energy of the proton in units of eV using engineering notation with best choice of prefix.
e) Determine the momentum (magnitude) of the proton. Answer in units of $\frac{\text{GeV}}{\text{c}}$.
f) Suppose momentum is doubled. By what factor does speed increase?